UNCLASSIFIED (1) AD-F000 009

THREAT HANDBOOK

BATTLEFIELD SURVIVAL AND RADIOELECTRONIC COMBAT

THE RADIO DIRECTION FINDING THREAT

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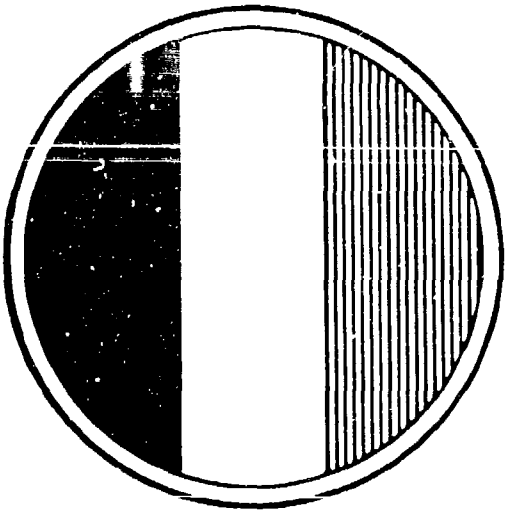

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FEBRUARY 1983

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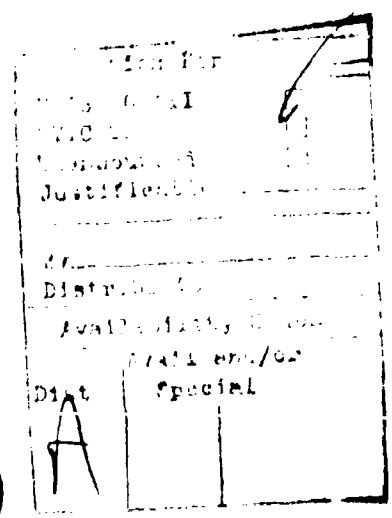
FOREWORD

The purpose of this training circular is to provide information concerning the radioelectronic combat threat. The enemy integrates electronic intercept and direction finding with suppressive fires and electronic jamming. Enemy radioelectronic combat is intended to deprive the United States Army use of its tactical electronic emitters required to fight the battle. This training circular explains how the direction finding component of enemy radioelectronic combat is used and how specific protective techniques may be applied to prevent United States Army units from becoming enemy electronic targets. This training circular is intended for use by all members of the United States Army having responsibility for tactical electronic systems.



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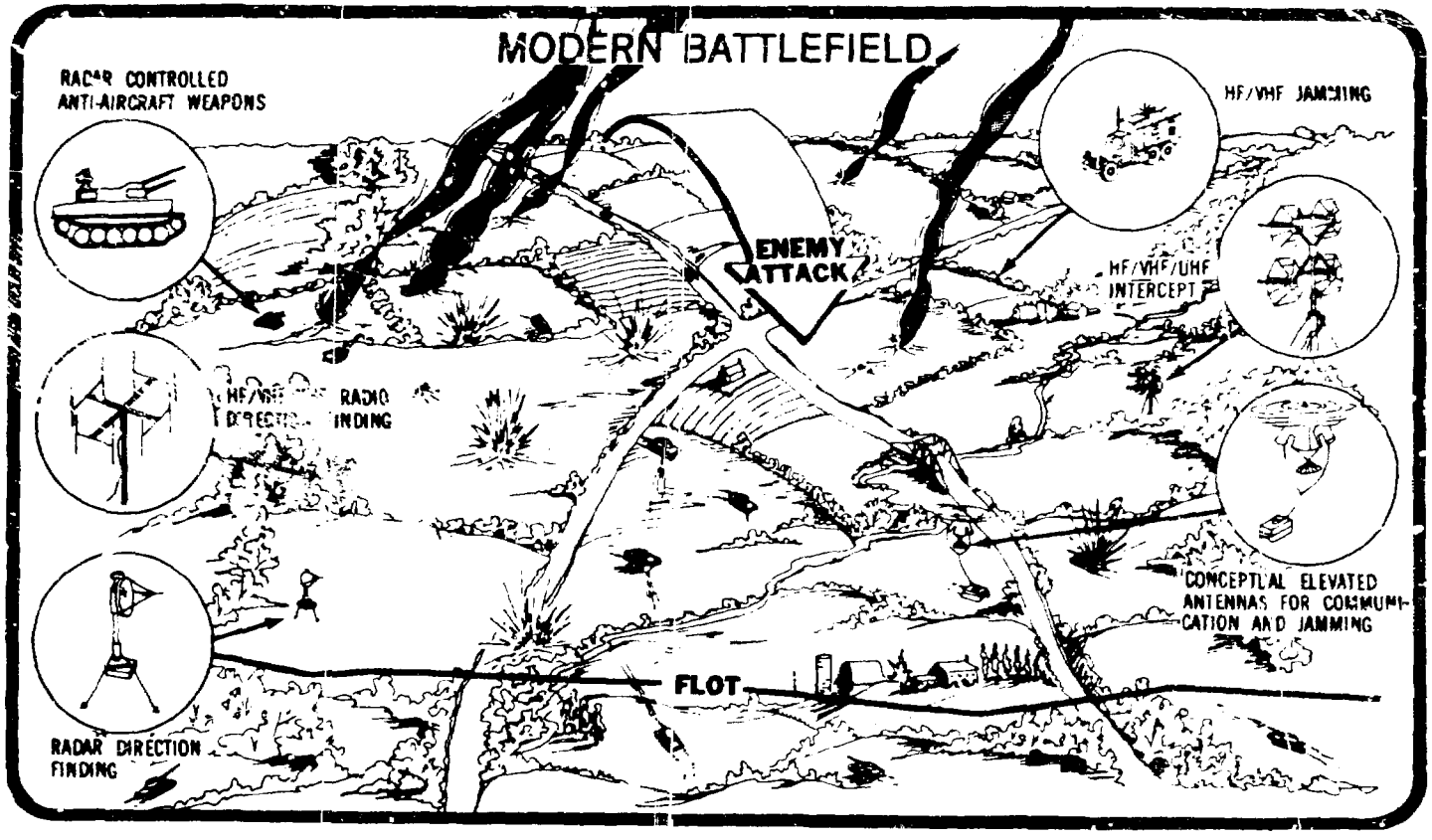
SECTION I

THE ELECTRONIC BATTLEFIELD

Consider the modern battlefield not in the customary three dimensions of previous wars — but with an added dimension — the electromagnetic spectrum. The commander must view and plan for this battlefield with regard to its depth and width, the airspace overhead, and the electromagnetic spectrum, a largely invisible medium which will saturate the battle area. If a unit can be seen visually or electronically on this battlefield, there is a high probability it can be destroyed. The enemy uses radio direction finding to locate electronic emitters used by our units. Once an emitter is identified and located the enemy can determine the disposition and intentions of our force and can also develop targets for suppressive fires or electronic jamming.

THIS TRAINING CIRCULAR EXPLAINS HOW DIRECTION FINDING IS USED AS AN ELEMENT OF ELECTRONIC WARFARE. THE EFFECTIVENESS OF ENEMY DIRECTION FINDING CAN BE REDUCED IF THE USERS OF ELECTRONIC SYSTEMS UNDERSTAND DIRECTION FINDING.

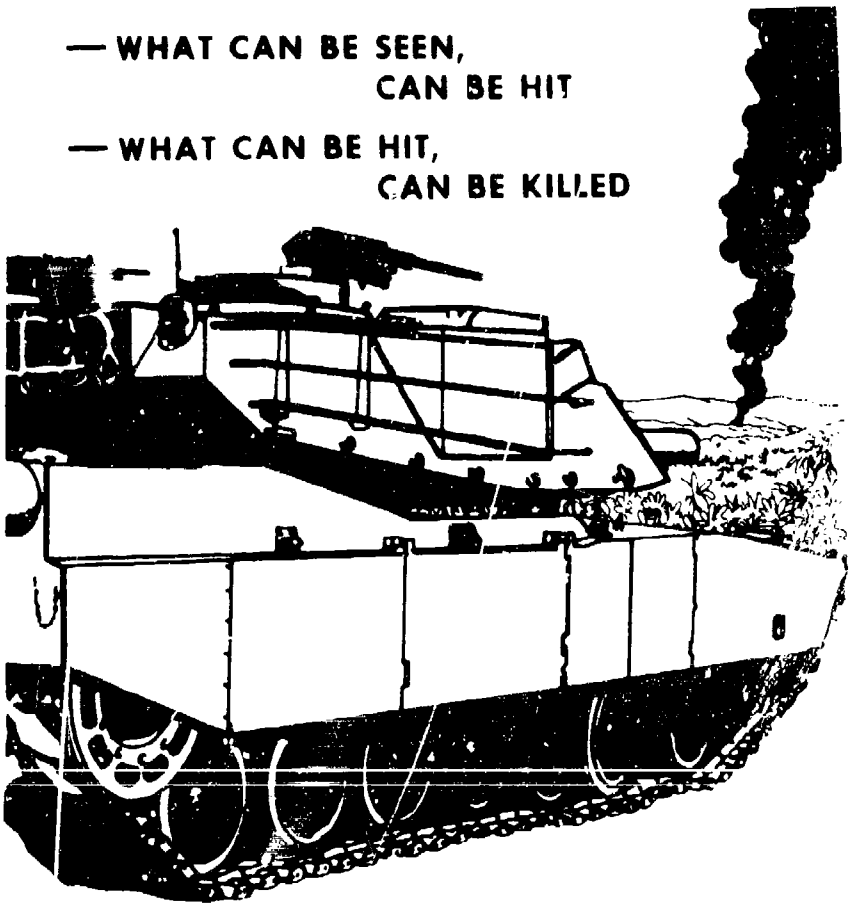


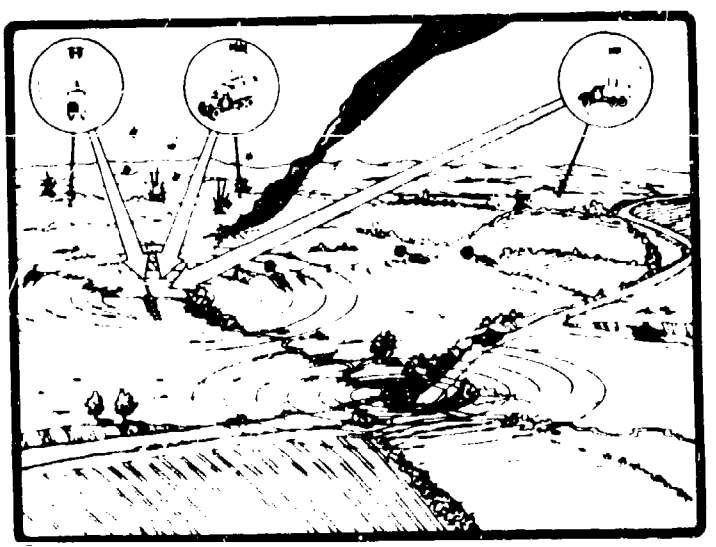
THERE ARE FOUR CHARACTERISTICS TO THE MODERN BATTLEFIELD:

1. It will be more lethal than ever before.
2. The US Army will fight outnumbered.
3. The integration of combat power and electronic warfare may be decisive.
4. What can be seen or heard ELECTRONICALLY can be targeted and can then be destroyed. Direction finding plays a key role in identifying and locating electronic emitters on the battlefield.

— WHAT CAN BE SEEN,
CAN BE HIT

— WHAT CAN BE HIT,
CAN BE KILLED

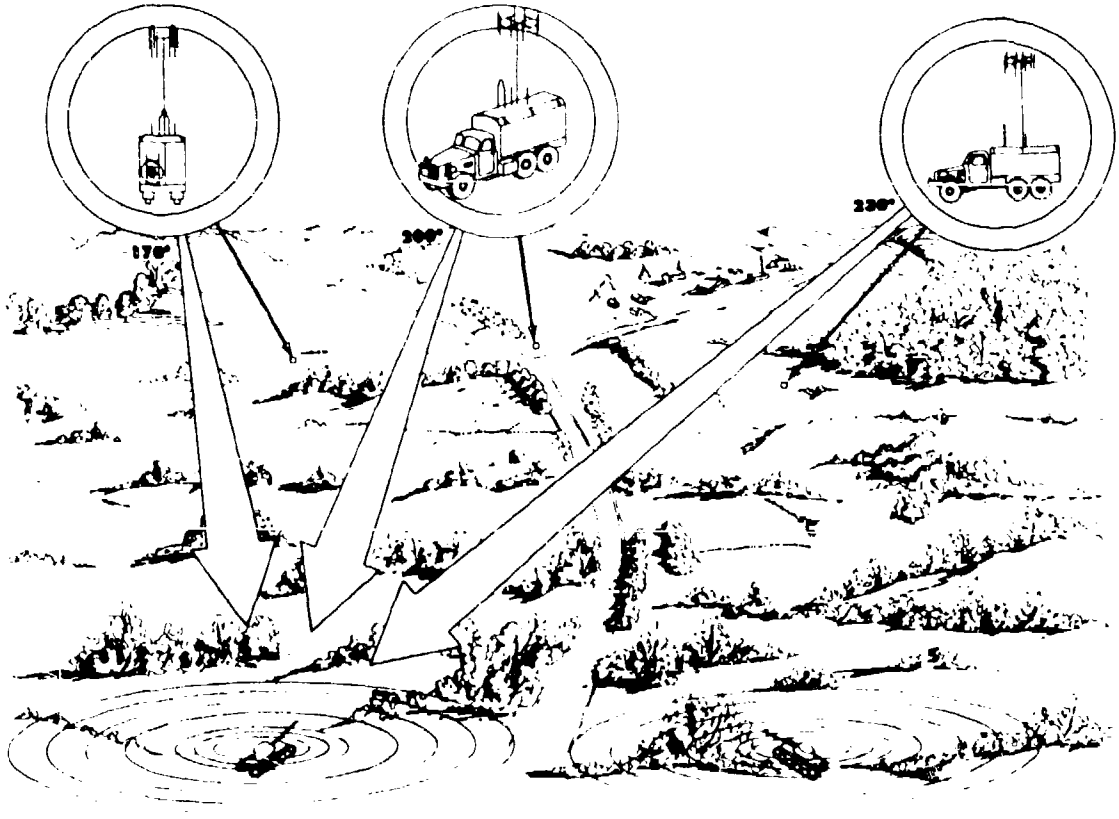




WHAT CAN BE SEEN VISUALLY OR
ELECTRONICALLY
CAN BE KILLED

DF
DIRECTION FINDING

DF is a collective term applied to the technique of determining line bearings from one or more direction finding positions to HF/VHF/UHF radio or radar emitters. A line bearing is determined by measuring the direction of arrival of an emitter's radio waves at the direction finders. A single line bearing from one point to an emitter provides the approximate direction of the emitter from the DF position. Intersecting bearings from DF positions at three or more different points may provide the approximate location of an emitter. Radars may be located very accurately by direction finding; in some cases by using only a single line bearing in conjunction with radar locating equipment.



DIRECTION FINDING IS USED TO LOCATE TARGETS

Radioelectronic combat is a term used by Soviet model forces to indicate the integration of signals intelligence (SIGINT), intensive jamming, deception, and suppressive fires to deprive an adversary of command and control in combat. It may be expected that enemy forces will be aware of the dependence that our forces place on communications. The enemy may be expected to try to systematically analyze US Army communications and noncommunications emitters which serve as keystones upon which command and control of our forces are dependent. The enemy may then be expected to attempt to destroy or disrupt at least 50 percent of our command, control, and weapon system communications by using suppressive fires or electronic jamming wherever possible. This is the essence of radioelectronic combat.

To locate US electronic emitters, the enemy employs direction finding in conjunction with other information to provide targets for enemy suppressive fires and jamming. Direction finding of radio transmitters is not precise. The enemy's suppressive artillery fires will usually not be fired at locations provided only by direction finding. However, there are exceptions.

Due to the high concentration and wide dispersal of multiple rocket launcher fires, they can be fired against soft targets located by direction finding with a high probability of destroying the target. Suppressive fires are also effective against most radars since they can be more accurately located by direction finding.

Because of the length of their transmissions, the peculiarity of their signal, and power output, jammers are easily located and identified as targets for attack by suppressive fires. Otherwise, the enemy requires information from other sources to refine direction finding locations into targets. In too many instances this information is provided by poor signal security (SIGSEC) or poor electronic counter-countermeasures (ECCM) on the part of our forces.

Because the US forces will be outnumbered, the US commander must be able to see the modern battlefield faster and more clearly than ever before. Accordingly, the US unit must depend on effective command, control, intelligence, and weapon communications systems for survival. Superb communications are needed to control the movement of forces to counter the enemy's superiority in numbers and firepower. The US Army needs and uses much communications equipment to fight a numerically superior enemy. To ensure that the US Army can fight in the manner for which it is being trained, it must prevent an enemy from controlling the electromagnetic environment.

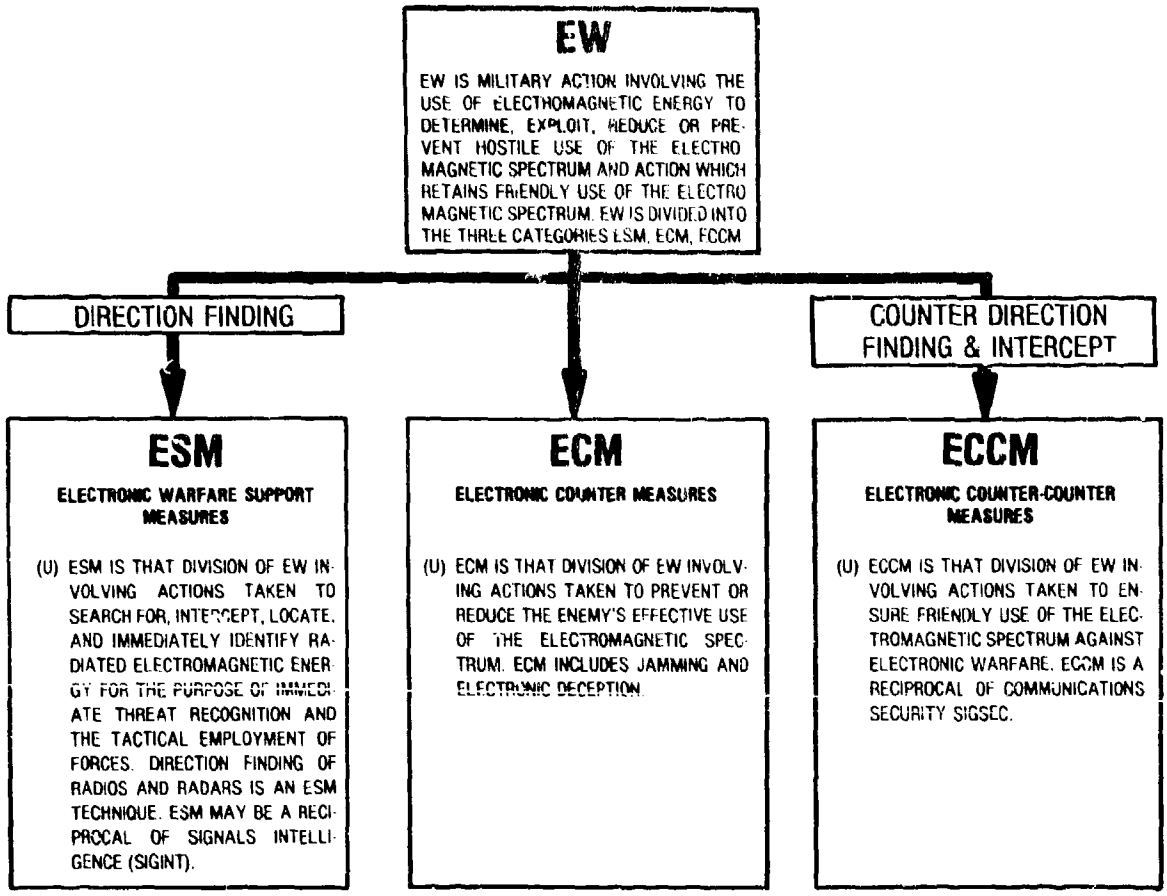
DIRECTION FINDING IS USED

- To provide approximate locations of electronic emitters that can then be fired on by artillery barrages or multiple rocket fires.
- To provide suitable locations for firing on most radars and jammers.
- To provide locations which, when applied in conjunction with signal and terrain analyses, can be refined to a target area of sufficient accuracy for artillery fires.
- To build a picture of the battlefield which shows the disposition and reveals the intentions of our units. The dispositions and intentions of units may be revealed by a single key emitter.

Specifically, direction finding is a prerequisite and essential step for the conduct of effective radioelectronic combat.

SIGSEC and ECCM are effective deterrents to enemy radioelectronic combat.

ELECTRONIC WARFARE


EW
EW IS MILITARY ACTION INVOLVING THE USE OF ELECTHOMAGNETIC ENERGY TO DETERMINE, EXPLOIT, REDUCE OR PREVENT HOSTILE USE OF THE ELECTRO MAGNETIC SPECTRUM AND ACTION WHICH RETAINS FRIENDLY USE OF THE ELECTRO MAGNETIC SPECTRUM. EW IS DIVIDED INTO THE THREE CATEGORIES ESM, ECM, FCCM
DIRECTION FINDING
COUNTER DIRECTION FINDING & INTERCEPT
ESM
ELECTRONIC WARFARE SUPPORT MEASURES
(U) ESM IS THAT DIVISION OF EW INVOLVING ACTIONS TAKEN TO SEARCH FOR, INTERCEPT, LOCATE, AND IMMEDIATELY IDENTIFY RADIATED ELECTROMAGNETIC ENERGY FOR THE PURPOSE OF IMMEDIATE THREAT RECOGNITION AND THE TACTICAL EMPLOYMENT OF FORCES. DIRECTION FINDING OF RADIOS AND RADARS IS AN ESM TECHNIQUE. ESM MAY BE A RECIPROCAL OF SIGNALS INTELLIGENCE (SIGINT).
ECM
ELECTRONIC COUNTER MEASURES
(U) ECM IS THAT DIVISION OF EW INVOLVING ACTIONS TAKEN TO PREVENT OR REDUCE THE ENEMY'S EFFECTIVE USE OF THE ELECTROMAGNETIC SPECTRUM. ECM INCLUDES JAMMING AND ELECTRONIC DECEPTION.
ECCM
ELECTRONIC COUNTER-COUNTER MEASURES
(U) ECCM IS THAT DIVISION OF EW INVOLVING ACTIONS TAKEN TO ENSURE FRIENDLY USE OF THE ELECTROMAGNETIC SPECTRUM AGAINST ELECTRONIC WARFARE. ECCM IS A RECIPROCAL OF COMMUNICATIONS SECURITY SIGSEC.

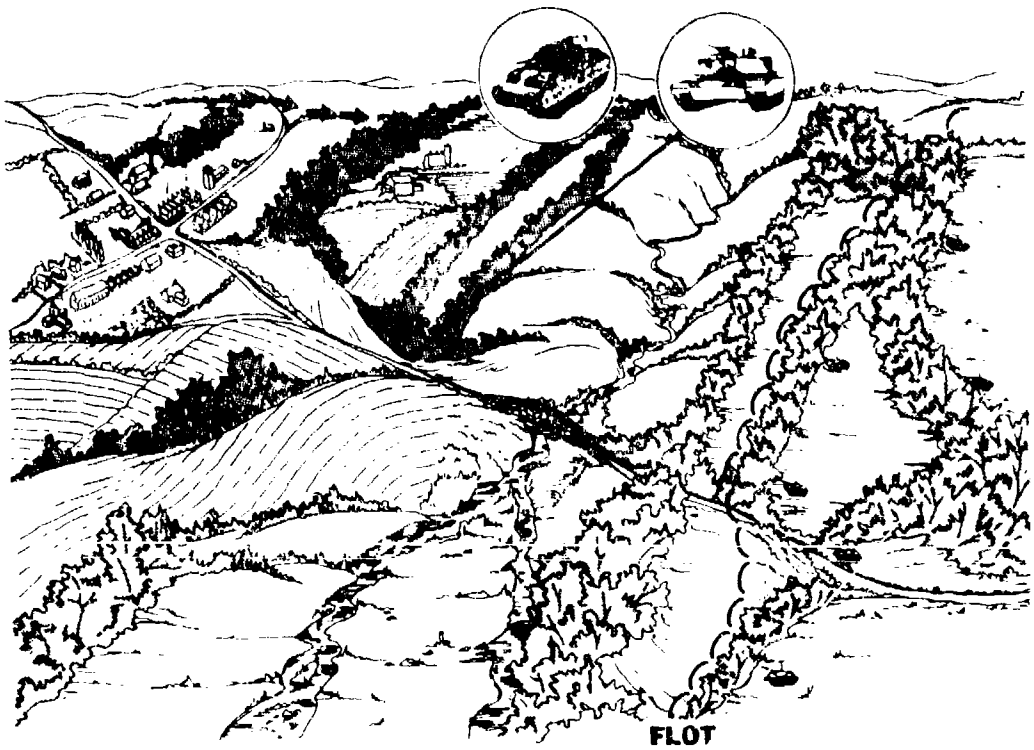
INTERCEPTING
IDENTIFYING
ANALYZING
LOCATING

JAMMING
DISRUPTING
DECEIVING

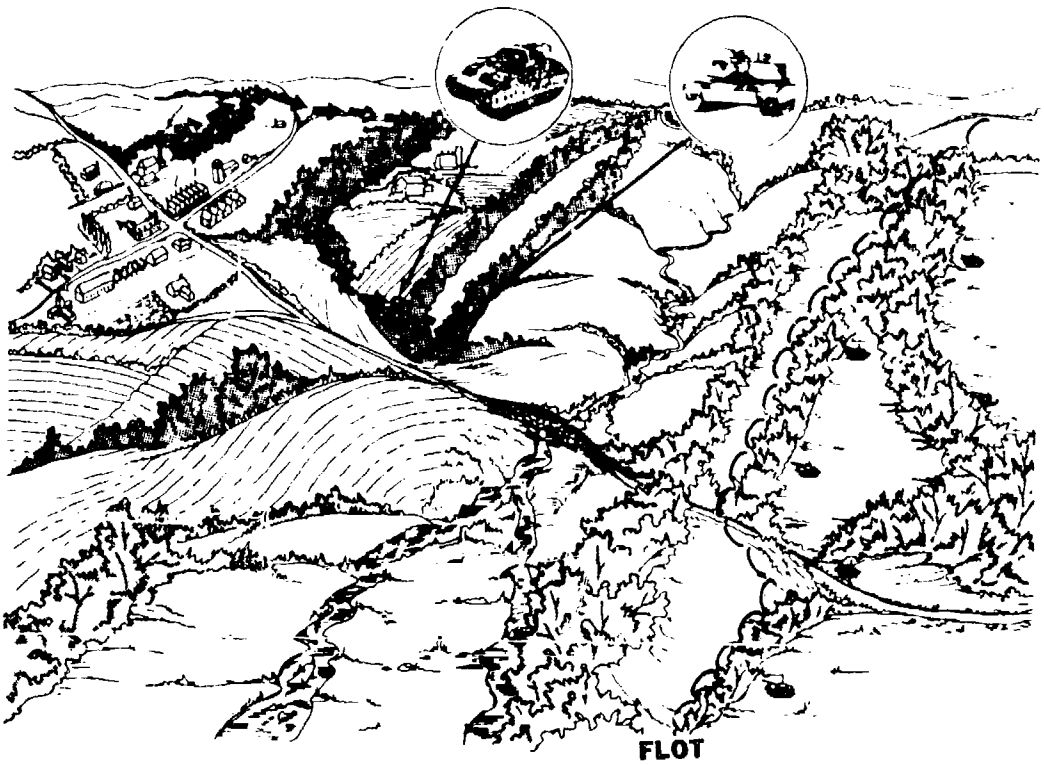
PROTECTING

SECTION II

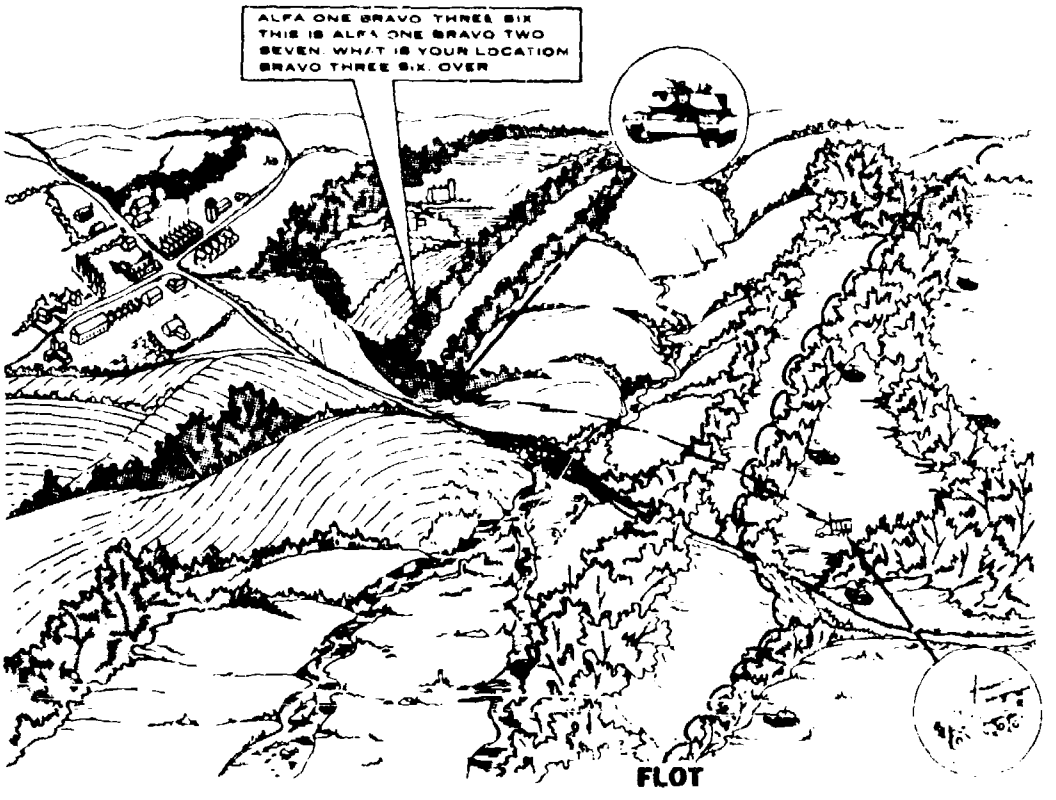
A SHORT HORROR STORY



A US Army mechanized force prepares to attack an enemy position on the hill mass to the east. One of its tank units is located off the adjacent road in a woodline near the bank of the stream. The tank unit is concealed and in defilade awaiting the arrival of a mechanized infantry unit approaching north of the town and from the west prior to attacking a fortified enemy position.

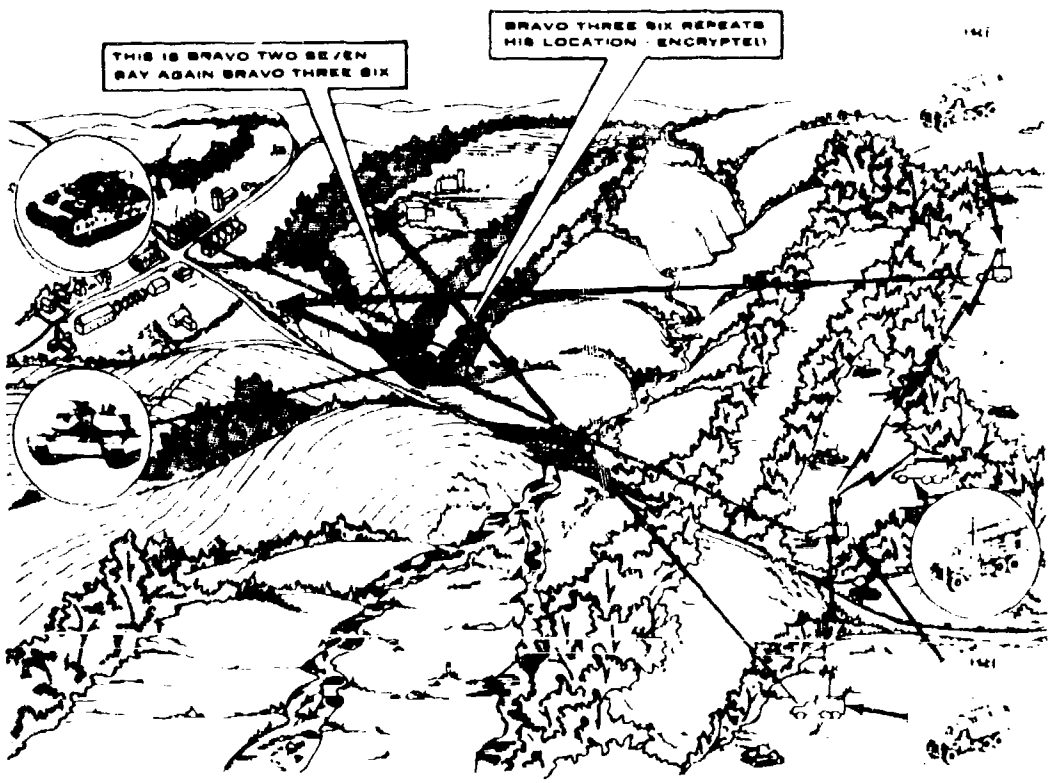


The mechanized infantry unit has passed north of the town and is approaching the tank unit while taking full advantage of all concealing terrain. At this point, both units remain visually unobserved by the enemy.

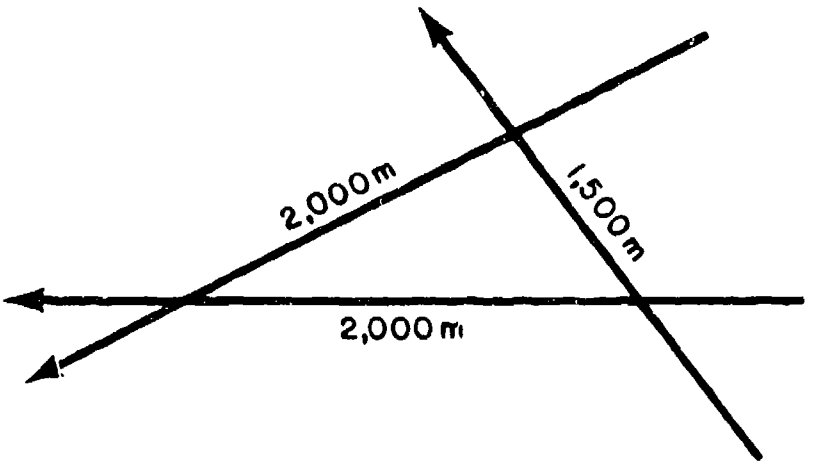


As the mechanized infantry unit approaches the general location of the tank unit, the commander requests further instructions. Communication time is about ten seconds. The enemy intercept operator monitoring the command net notes and records the communication.

The tank unit replies, providing its location with a properly encrypted message. Communication time is about twenty seconds. At this point the enemy intercept unit has flashed its direction finding net asking for bearings on both stations transmitting on the monitored frequency.

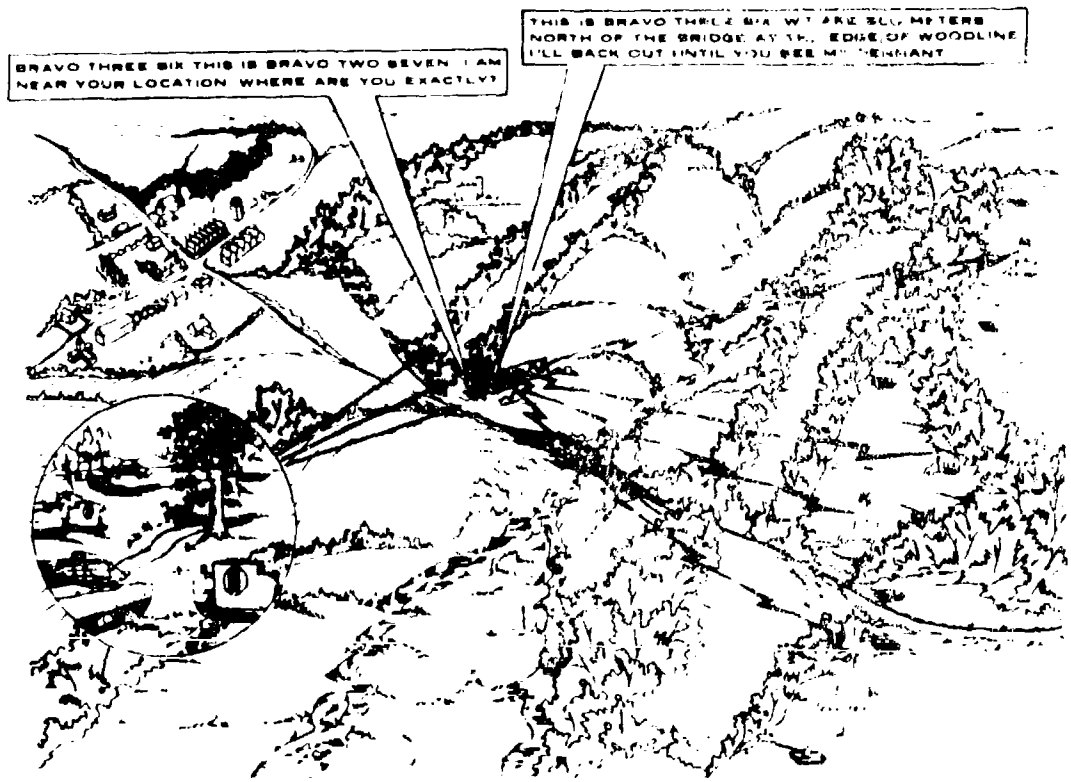


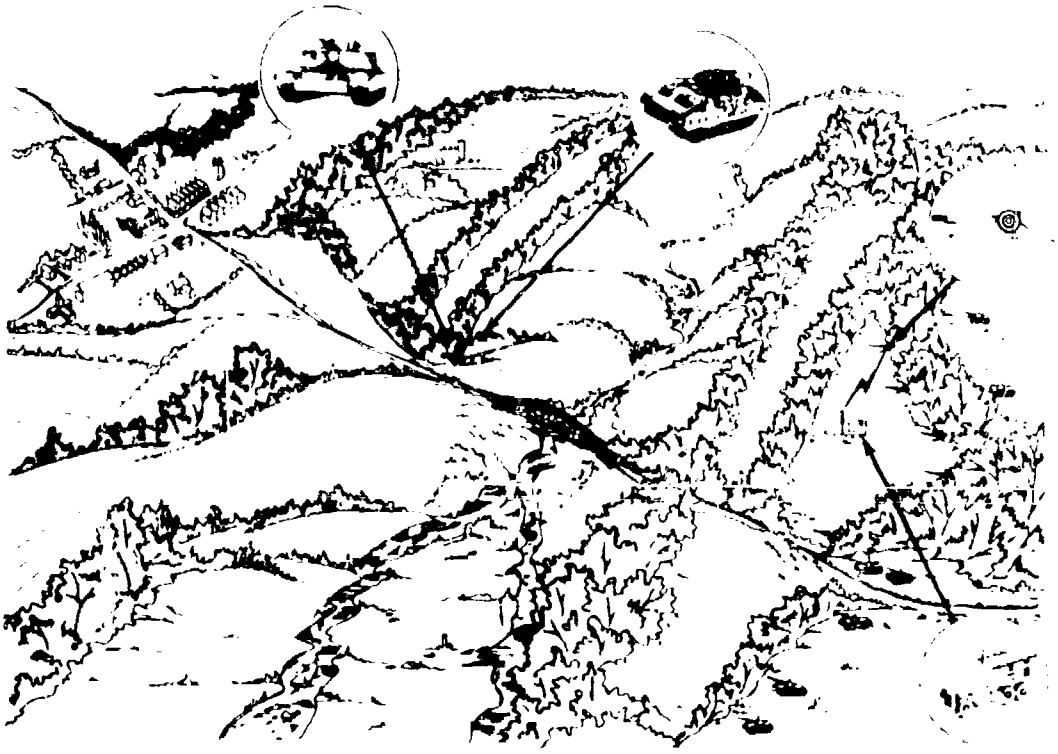
Total time for the entire communications exchange is about forty-five seconds. The enemy radio direction finding (RDF) net has had more than adequate time to determine the azimuth from each of its three positions to the tank unit. The area within the triangle on the map represents the approximate RDF fix.



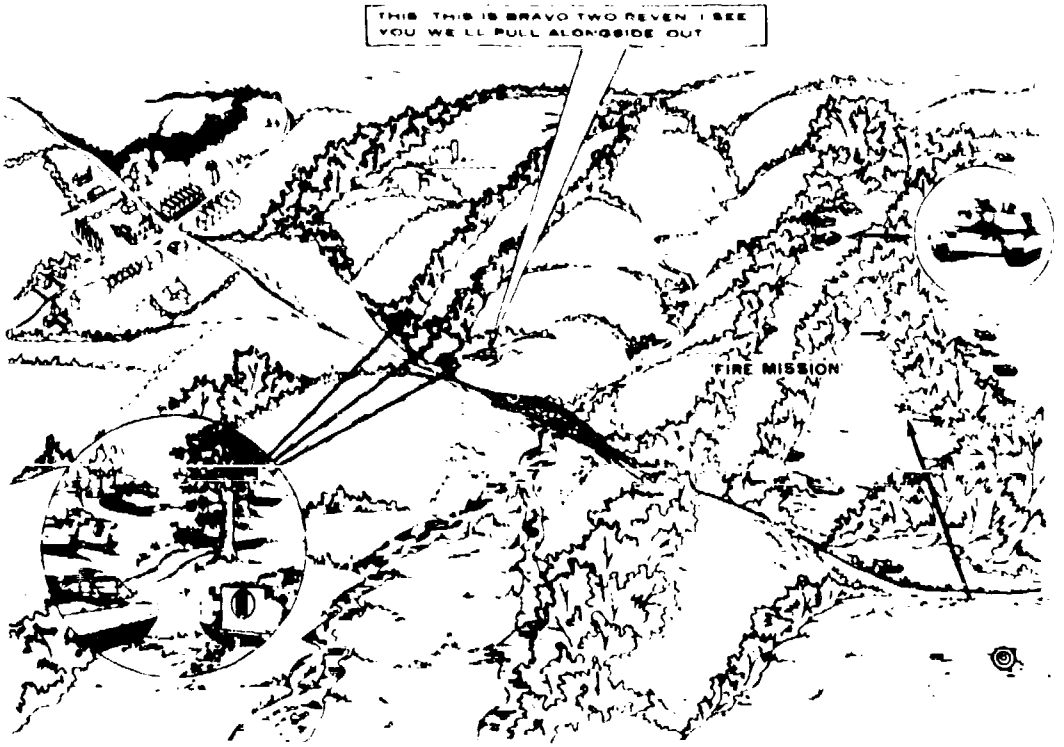
The area of the fix remains too large for accurate targeting or to risk exposing the enemy's firing positions on the hill to the front. The gridded location of the tank platoon reported in the communication was properly encipered and remains unintelligible to the enemy. In fact, most things are being done correctly. A combined arms team is being used to attack fortified positions and the team is using concealed routes of advance. But, the enemy does know that the mechanized unit is moving to the tank unit's location within the triangular area delineated by the RDF. The enemy knows that there will soon be two targets within the triangular area. Further, elementary call sign analysis suggests that two separate units are involved. If the new automated communications-electronic operating instructions (CEOI) are not used correctly, prior tactical call sign analysis by the enemy would suggest that a tank unit and a mechanized unit are involved. Plain text revelation not involving call sign usage but the use of tanker- or mechanized infantry-peculiar terms would also allow this conclusion.

BRAVO 27 is now about 1,000 meters from the tank unit but is unable to see the concealed tanks. BRAVO 27 has no intention of remaining in the open or of getting lost near the FLOT so . . .


BRAVO THREE SIX THIS IS BRAVO TWO SEVEN I AM NEAR YOUR LOCATION WHERE ARE YOU EXACTLY?
THIS IS BRAVO THREE SIX WE ARE 500 METERS NORTH OF THE BRIDGE AT THE EDGE OF WOODLINE I'LL BACK OUT UNTIL YOU SEE ME



Meanwhile, on the hill to the front, the enemy gunners have received preliminary information for a fire mission. Traverse and elevation is completed, the guns are loaded, the gunners are awaiting the order to fire. Only the most basic analysis was required to locate the "bridge" within the vicinity of the RDF location, from there the woodline was readily located. There was more than adequate information with which to provide a target.

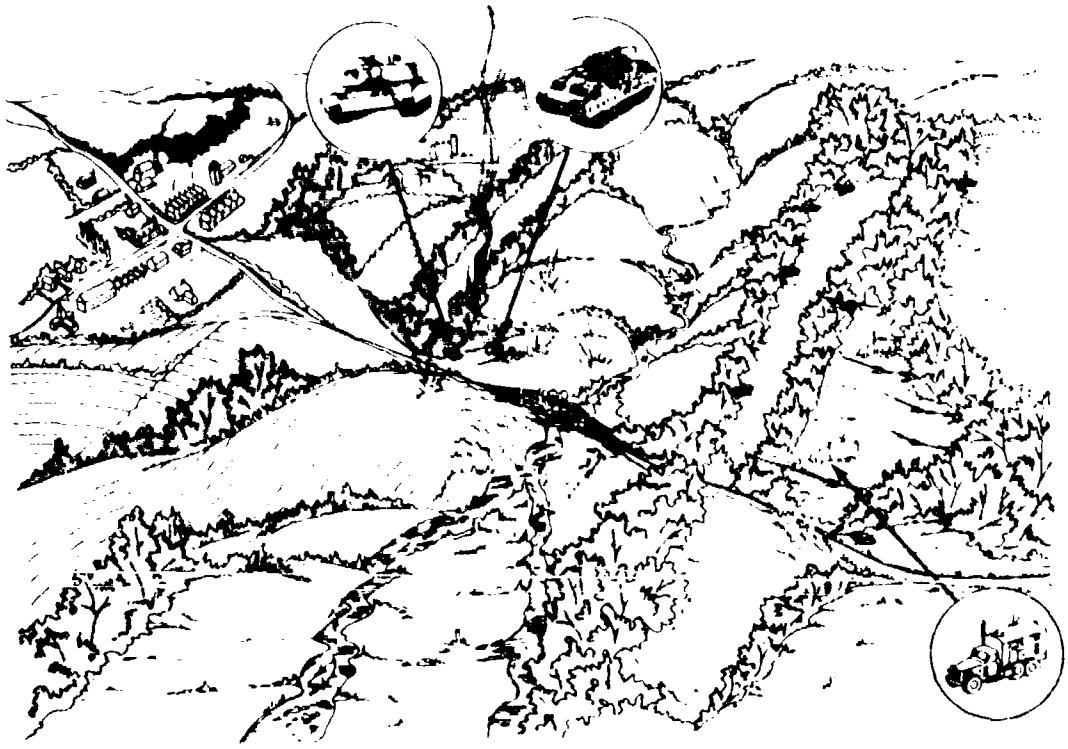


The enemy artillery commander allows another minute or so for the armored personnel carriers (APC) to close with the tanks and for hatches to open and then the APC and tank engines are muffled by the sound of exploding artillery aimed 500 meters north of the bridge at the edge of the woodline.

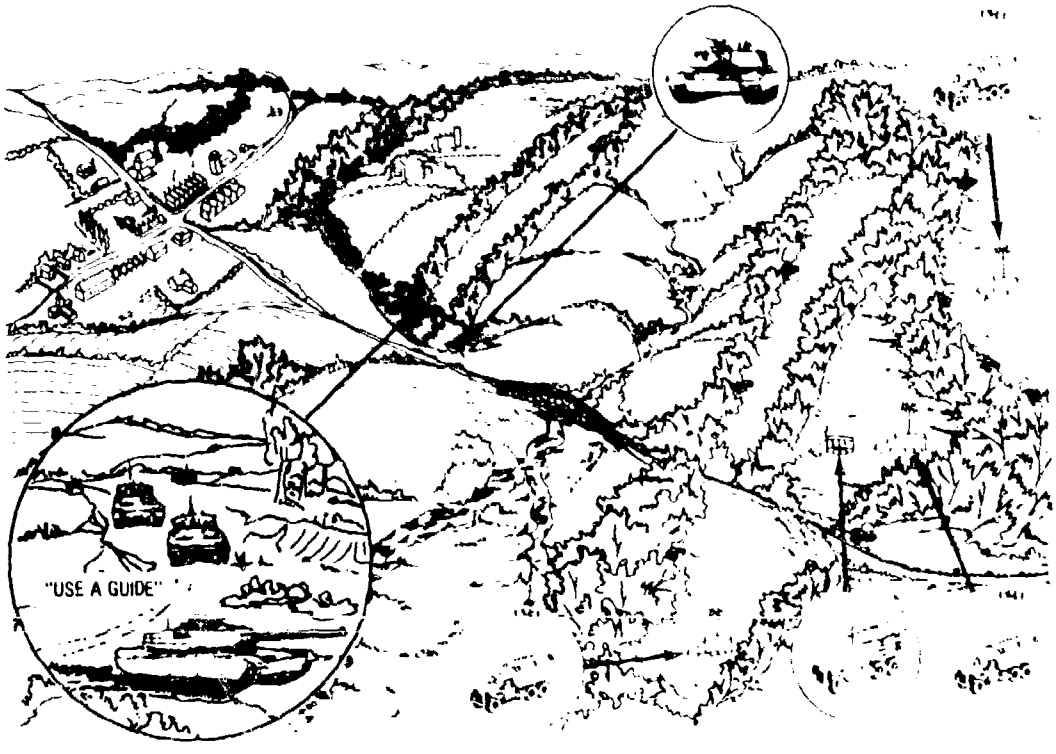
Hopefully, the lesson to be learned from the horror story is not that enemy RDF is highly accurate, but that . . .

POOR COMSEC IS SUICIDE

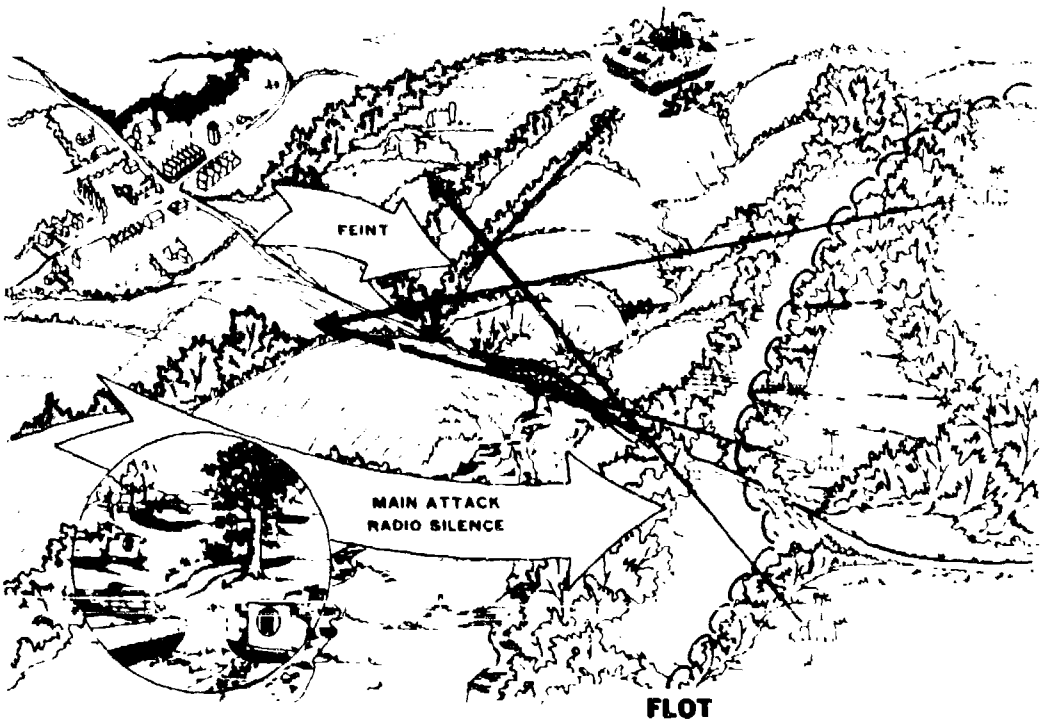
During a three-day maneuver in 1982 about 60 percent of all battalion and brigade command posts within a US Army division were located to within 500 meters in this manner.



If the enemy is unable to destroy the friendly unit by suppressive fires, he will target the friendly unit's receivers for radio jamming during the attack on his positions when command and control by our forces are crucial. RDF and poor communications security (COMSEC) permit the enemy to accurately direct his jammers against our radios for maximum effectiveness.



In the preceding scenario the use of a predetermined approach route for the mechanized infantry unit and the use of guides provided by the tank unit could have avoided the use of communications. This is one method that the enemy forces use to reduce communications.



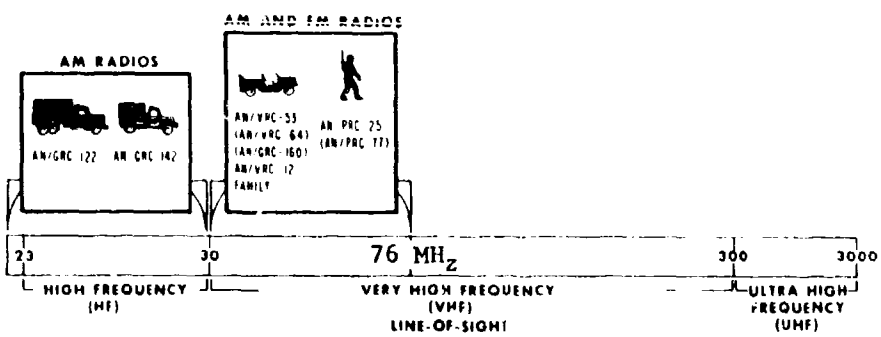
This scenario also provided an excellent opportunity for electronic deception. A feint suggesting a frontal attack north of the road could have been simulated with only one tank and one APC using noise broadcast equipment to simulate the engine sounds of the tanks and APCs of a larger force. Manipulative communications deception (MCD) by the tank and APC indicating a much larger force would have contributed additional realism to the feint by feeding the enemy false RDF conclusions. Meanwhile the actual force conducting the main attack approaches from the south with emission control (radio silence). The enemy's artillery is directed to the wooded, but then unoccupied, area "500 meters north of the bridge" and the attack is successful and casualties hopefully reduced. Deception is a good idea, but must be carefully planned and coordinated with battle commander and adjacent units. Since the enemy may also use ground radar to verify these targets, the deception force should include a deception array.

SECTION III

RADIO WAVES

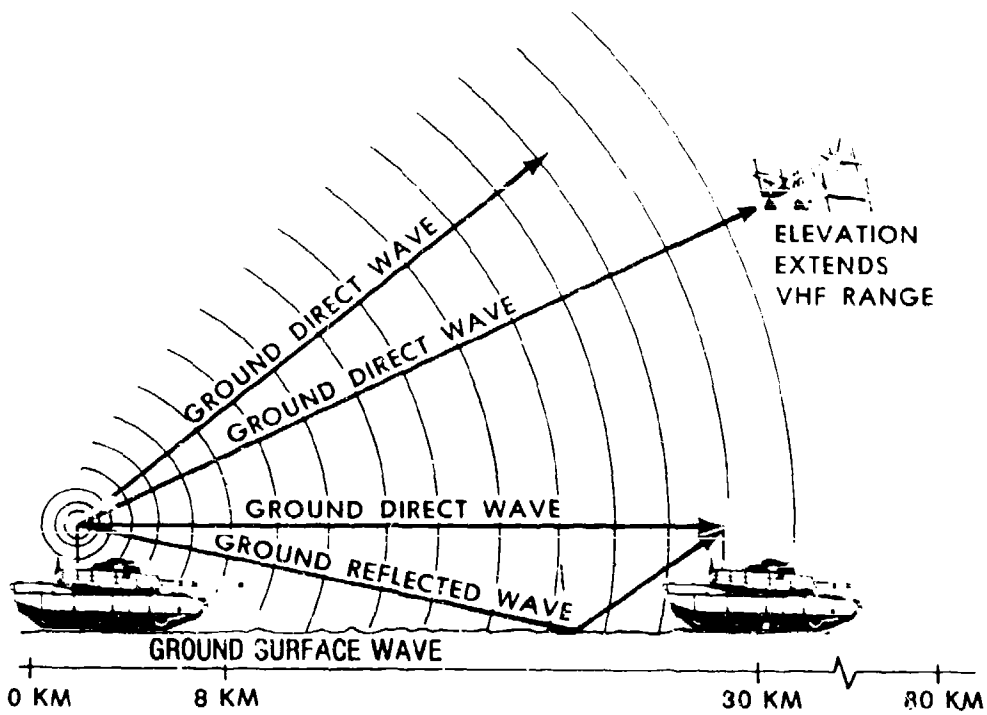
The accuracy of RDF has been the subject of many narratives. In some cases commanders who believe that RDF is very precise instruct that radios and their antennas be remoted 250 meters from the operator to counter RDF. Remoting only 250 meters is of little advantage. Let's examine the facts. A basic explanation of radio wave theory is essential in order to understand direction finding accuracy.

The ability of a direction finding station to intercept and determine a bearing on a target transmitter depends on its ability to receive a "usable" signal. A usable signal depends on the characteristics of radio waves. Radio waves travel from the transmitter to a receiver or direction finder by ground wave which spreads directly from transmitter to receiver through or just above the soil or sea; and by sky wave which travels up to the electronically conducting layers in the earth's upper atmosphere and is reflected back by these layers to earth. In the past the Army has referred to its tactical field radios chiefly as amplitude modulated (AM) or frequency modulated (FM). This practice dates to WW II when the terms AM and FM more clearly distinguished the versatility of these two types of radios. With respect to electronic warfare (EW) commanders should perceive tactical radios with respect to the behavior of the radio's signal (radio wave propagation) which is affected mostly by frequency.



CONSIDER RADIOS NOT ONLY AS AM OR FM BUT ALSO AS HF, VHF, OR UHF

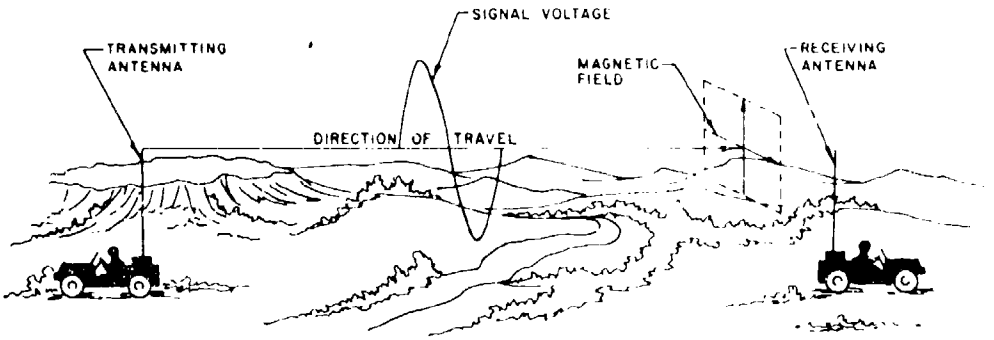
Long distance (600 km +) HF (3-30 MHz), radio transmission takes place principally by means of the sky wave; short distance HF (50 kms) uses the ground wave. Tactical FM communications (like the AN/PRC-77) use VHF. VHF (30-300 MHz) (often called tactical FM) communication is a radio line-of-sight, short distance (40 to 80 kms), radio transmission method. The AN/PRC-77 and VRC-46 series radios use a portion of the VHF spectrum (30-76 MHz). The range of the VHF ground wave depends on the unobstructed line-of-sight distance from the transmitting to the receiving antenna, the height and type of the antennas, and the effective power output of the transmitter. Enemy direction finding can be restricted by controlling the direction and power of the radio's ground wave. A VHF transmission is illustrated below.



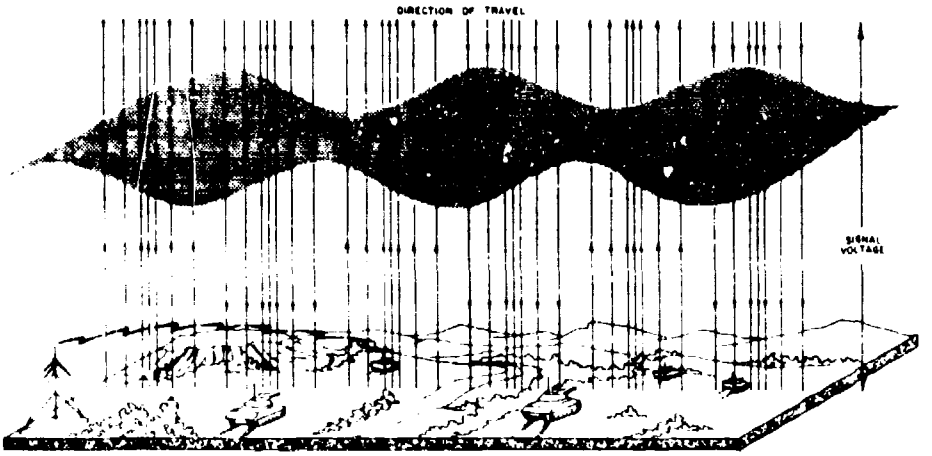
THINK AND VISUALIZE "VHF" BEHAVIOR RATHER THAN "FM" FOR ELECTRONIC WARFARE

ANTENNA POLARIZATION AND DIRECTIVITY

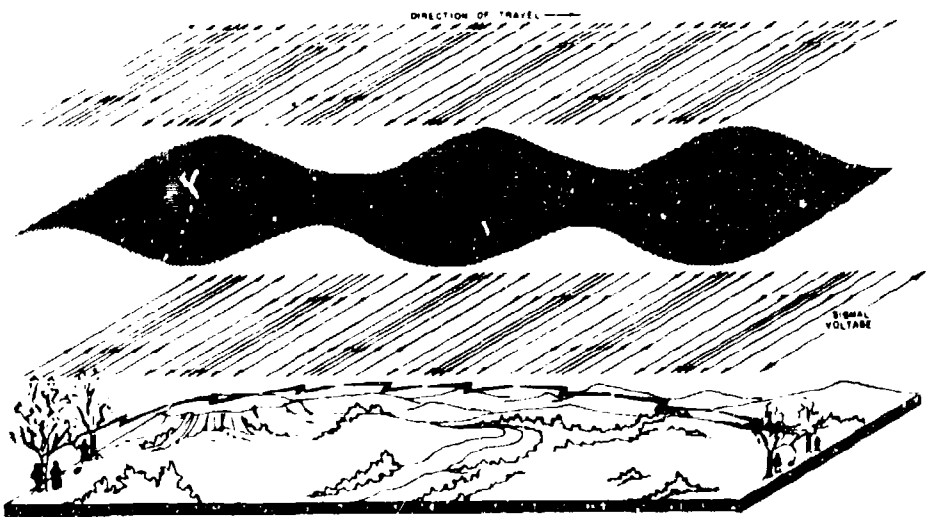
When power is delivered to an antenna, a radiation field is established which travels from the transmitting antenna into space and hence to receiving antennas. The radiation field has two components, referred to as the electric and magnetic fields, which form a definite pattern, depending on the type antenna used.



Polarization of a radiated wave is determined by the direction of the lines of force making up the electric field. Lines of force at right angles to the earth are called *VERTICALLY POLARIZED*; lines which are parallel to the earth are called *HORIZONTALLY POLARIZED*. Vertically polarized antennas are used for efficient reception of vertically polarized lines of force; similarly, horizontally polarized antennas are used for efficient reception of horizontally polarized lines of force. Commanders at every echelon need to understand how to advantageously use vertically and horizontally polarized antennas. They need to understand that vertically polarized antennas provide the best flexibility in the attack when rapid movement detracts from enemy DF. The horizontally polarized antenna provides the best security in the defense and longer range when transmitting in heavily wooded areas. The unit communications-electronics officer should be consulted with regard to the proper use of all antennas.



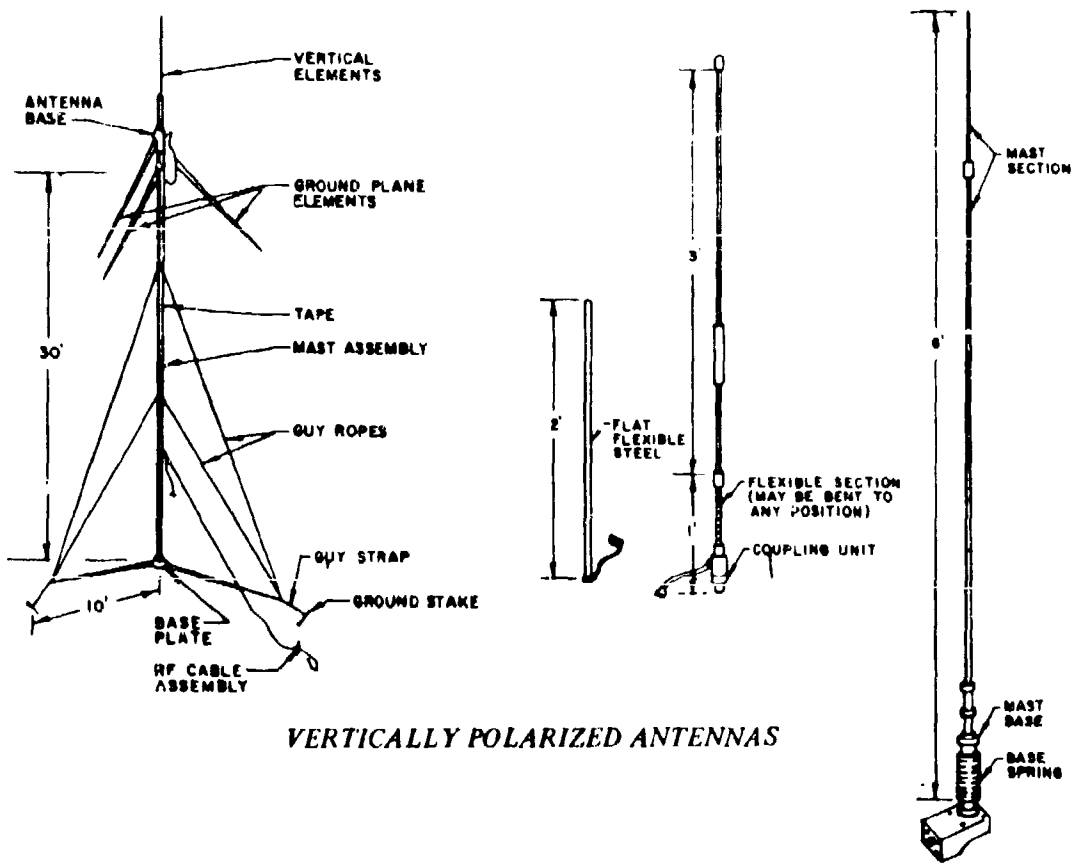
VERTICAL POLARIZATION USING VERTICALLY POLARIZED -OMNI-DIRECTIONAL ANTENNAS



HORIZONTAL POLARIZATION USING HORIZONTALLY POLARIZED ANTENNAS

Either vertically or horizontally polarized antennas may be used at VHF. Vertically polarized antennas are more common for military communications because they can produce an omnidirectional signal (radiating in 360 degrees) and hence are very versatile. Omnidirectional signals are, however, more likely to be intercepted by the enemy. Horizontally polarized antennas are directional. Both vertically and horizontally polarized signals can produce dead areas, called *nulls* — zero signal — which can be oriented toward the enemy to reduce the probability of intercept when directional antennas are used. Vertically polarized VHF signals are also stronger at 30 to 50 MHz with antenna heights under 10 feet; above 50 MHz there is no practical difference between the signal strength produced by vertically and horizontally polarized antennas.

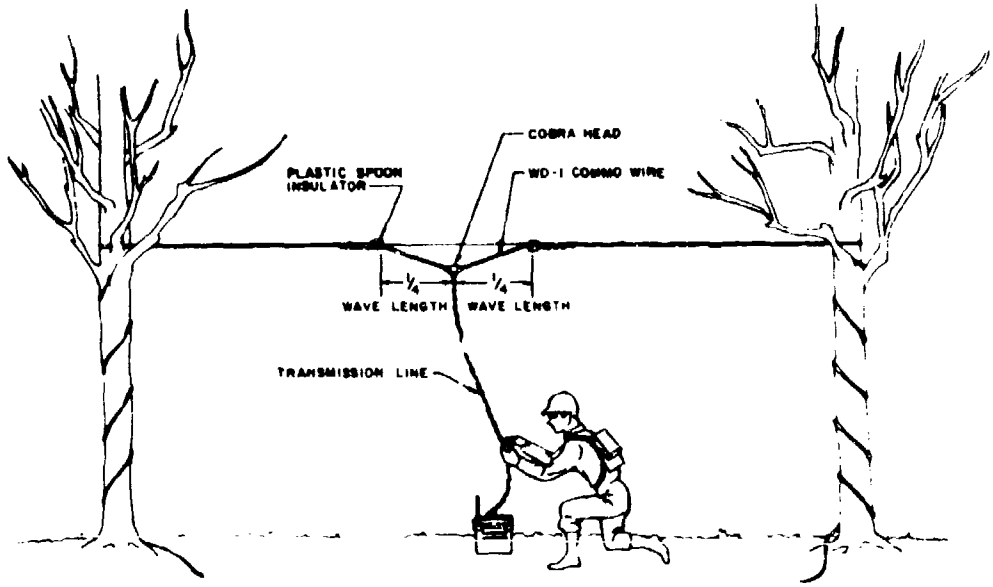
Use of a horizontally polarized antenna reduces vulnerability to intercept and radio direction finding. A steerable, vertically polarized antenna will also reduce the vulnerability of radio emitters to intercept and radio direction finding. That's it — the basic principles.



VERTICALLY POLARIZED ANTENNAS

*The OE 254 antenna has replaced the RC 292 antenna shown above in some units. However, the basic principles discussed here remains constant.

As an example, at 30 MHz each half of this quarter-wave antenna is 2.5m long and at 76 MHz only 0.987m long. (See page 74 for an example on how to construct this antenna.)



AN/PRC 77
RADIO

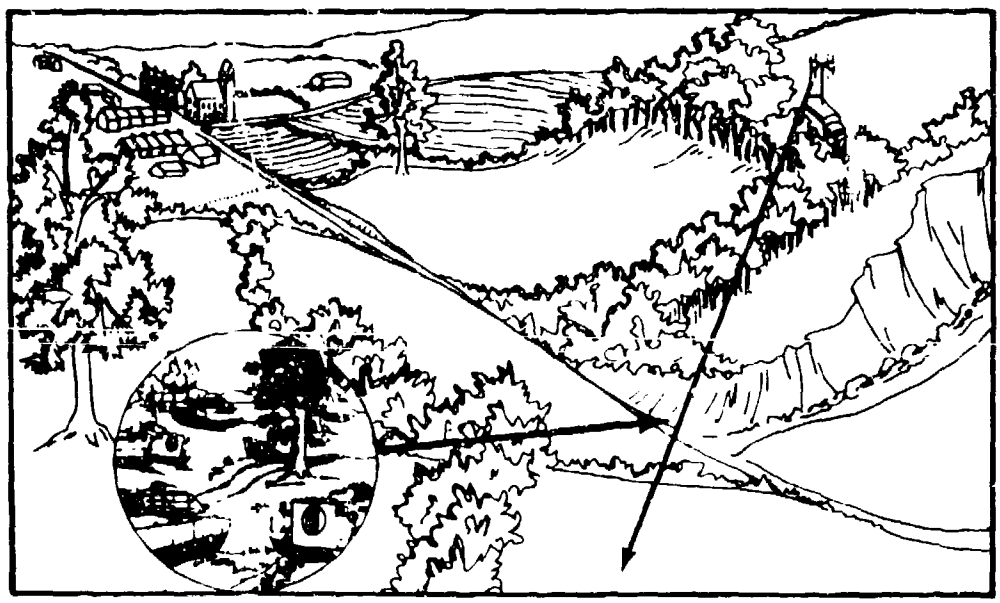
HORIZONTALLY POLARIZED ANTENNA

SECTION IV

HOW DOES RADIO DIRECTION FINDING WORK?

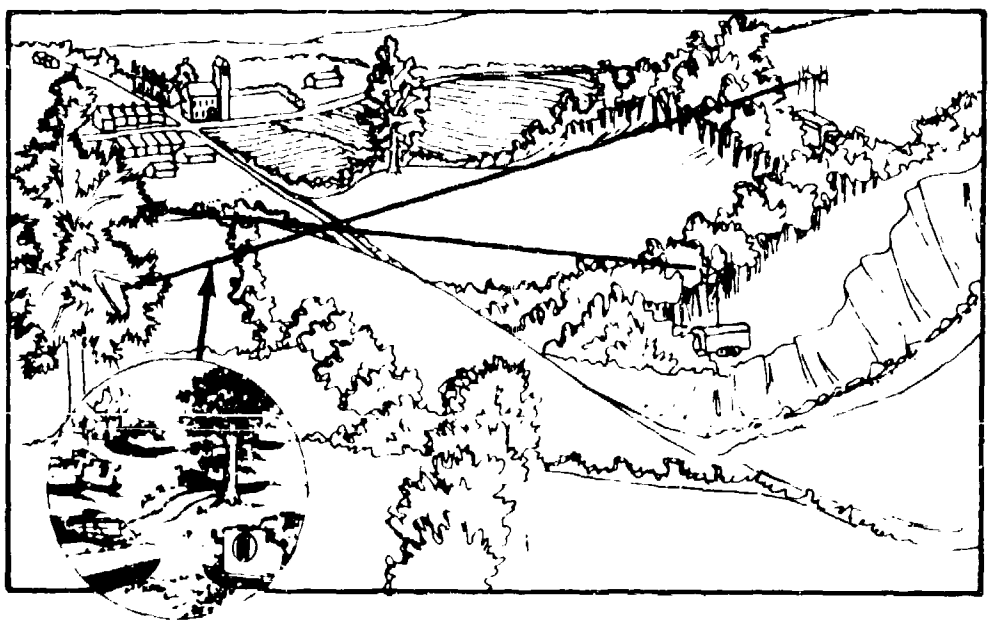
Radio direction finding is a method of determining the approximate direction of a transmitting antenna (radio or radar) by means of its emissions at a single direction finding position. Direction finding can also determine the approximate location of an emitter by correlating the directions of arrival of its several emissions by a direction finding location and identification system which may consist of one (but usually three or more) positions.

"A BEARING"



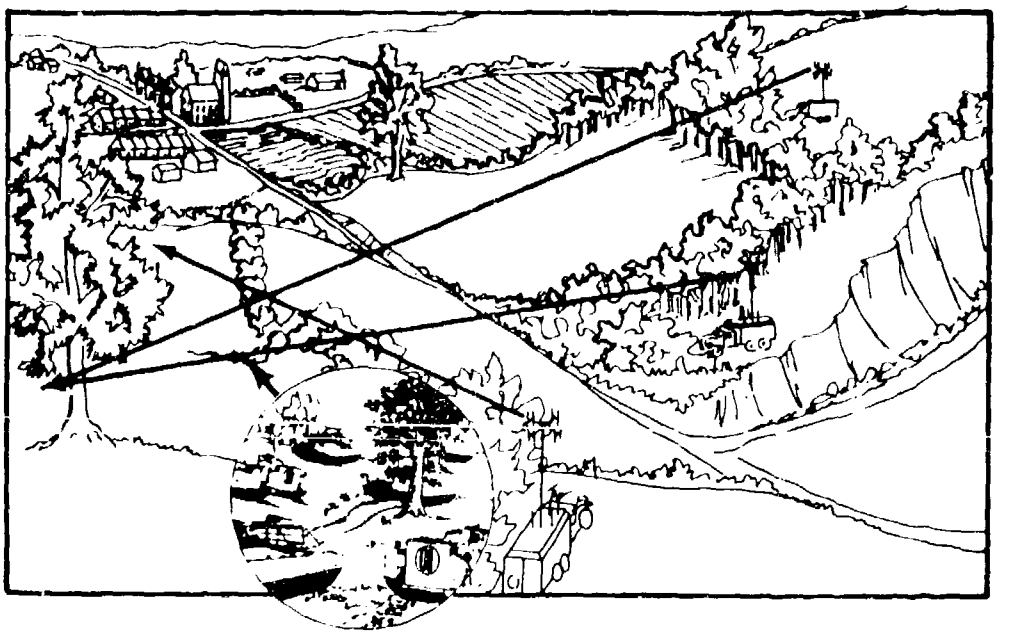
One RDF bearing provides *APPROXIMATE* direction, but not distance.

"A CUT"

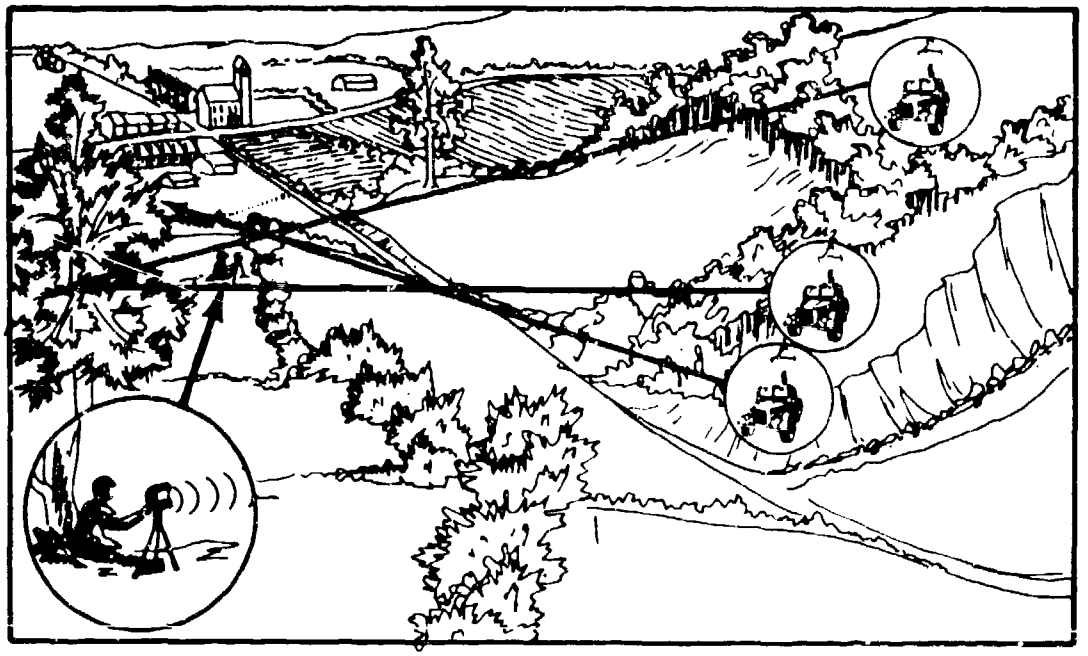


Two RDF bearing usually provide *APPROXIMATE* direction and *SOME CONCEPT OF* distance.

"A FIX"



Three or more RDF bearings are referred to as a fix. A fix usually provides better direction and distance to form an *APPROXIMATE* location.

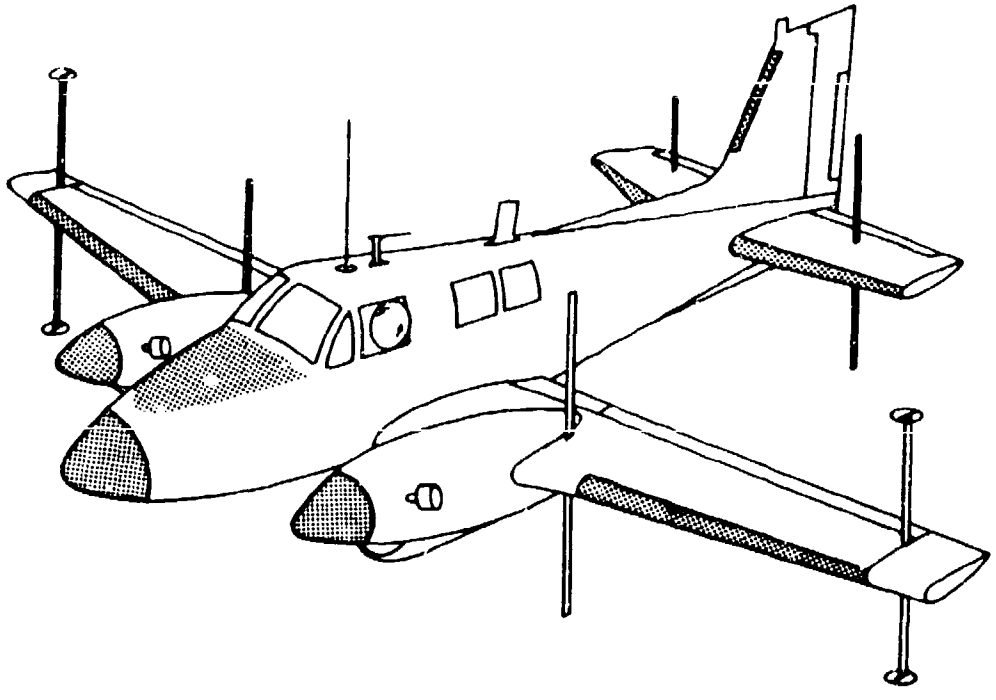


The same principle applies to locating radar equipment, but the enemy uses DF equipment that is compatible with radar signals. Radars may be located more accurately than radios due to their signal characteristics, and within a triangle or circle having a radius of 50 to 200 meters.

SECTION V

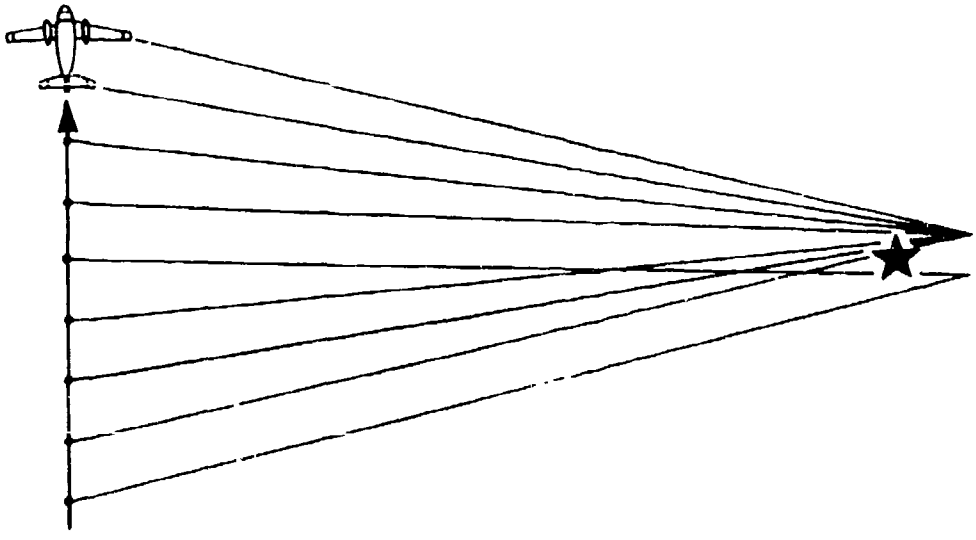
HOW AIRBORNE RADIO DIRECTION FINDING WORKS

Airborne radio direction finding (ARDF) is a radio direction finding system mounted in a helicopter or a fixed-wing aircraft. The principles of ARDF operation are similar to those which govern ground vehicle radio direction finding. But, the use of an airborne platform increases the elevation of the receiving antenna and enhances its ability to intercept radio signals at greater distances.

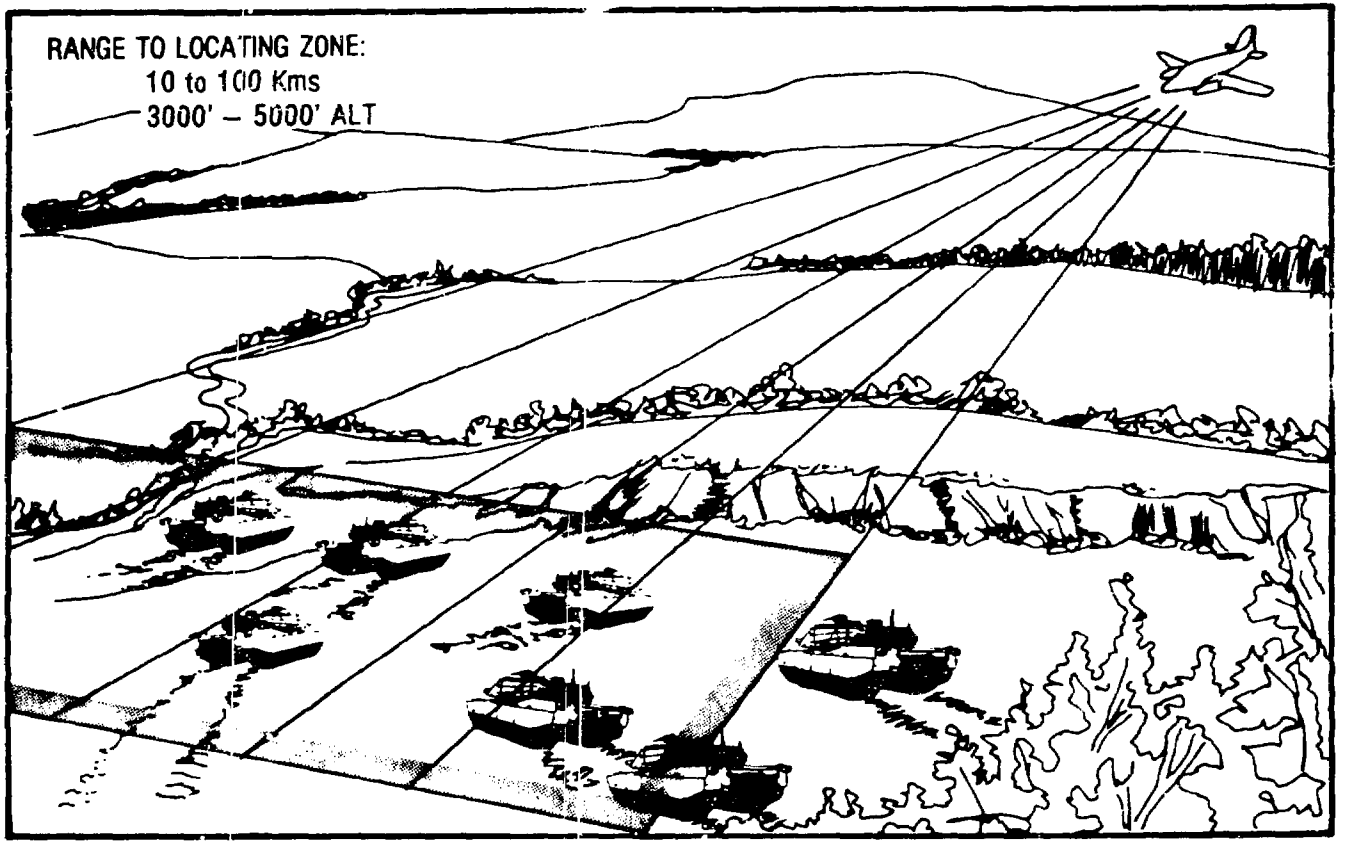


ARDF is not subject to as many effects of propagation error as is ground station RDF. As an example, an aircraft can take a series of successive bearings along its flight path and provide the effect of many ground station RDF bearings without the limitation of individual ground station error factors. (In many situations, individual ground station error factors accumulate to produce gross errors.) In some instances, the aircraft can also pursue the target transmitter while further refining its bearing at closing ranges. In this respect, ARDF is a special threat to unconventional warfare and long-range reconnaissance units.

AIRBORNE RADIO DIRECTION FINDING FIX

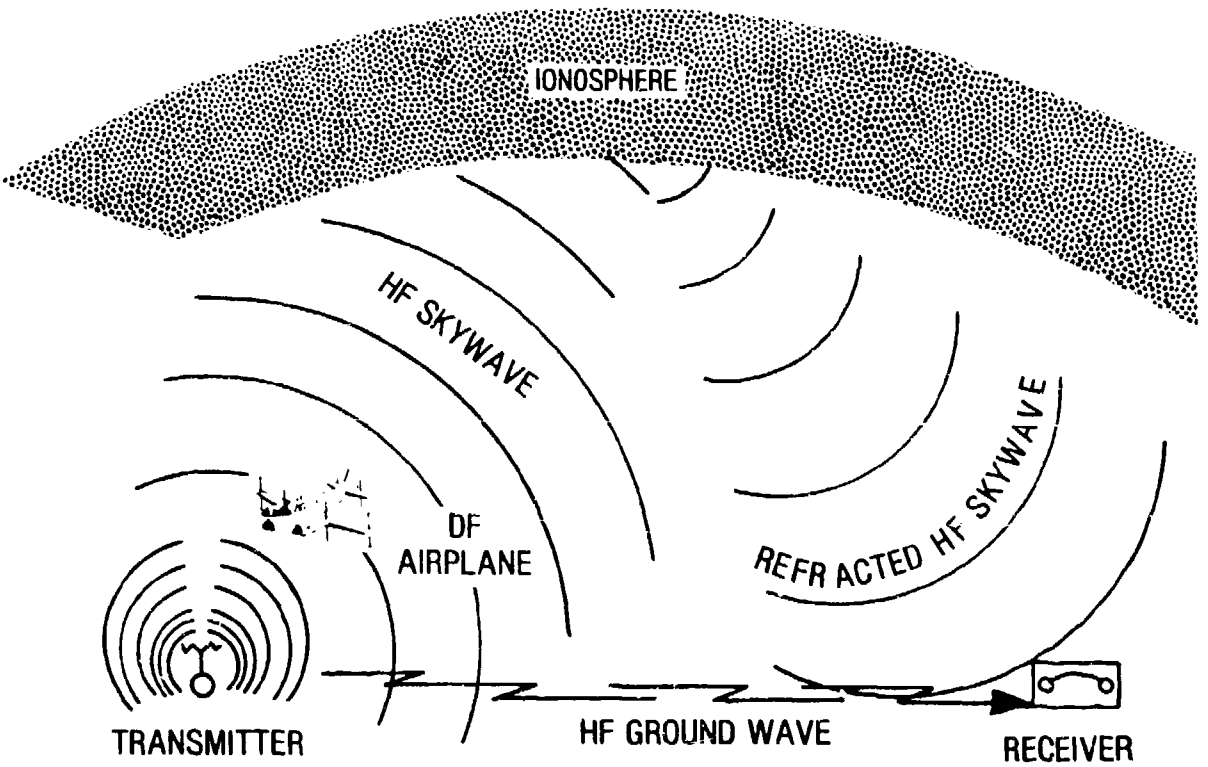


More azimuths and better accuracy are possible with ARDF, but the aircraft is required to remain on track long enough to acquire a wide base for the DF bearings. If the aircraft is diverted (as by anti-aircraft artillery (AAA) fire), then the bearings will be distorted.



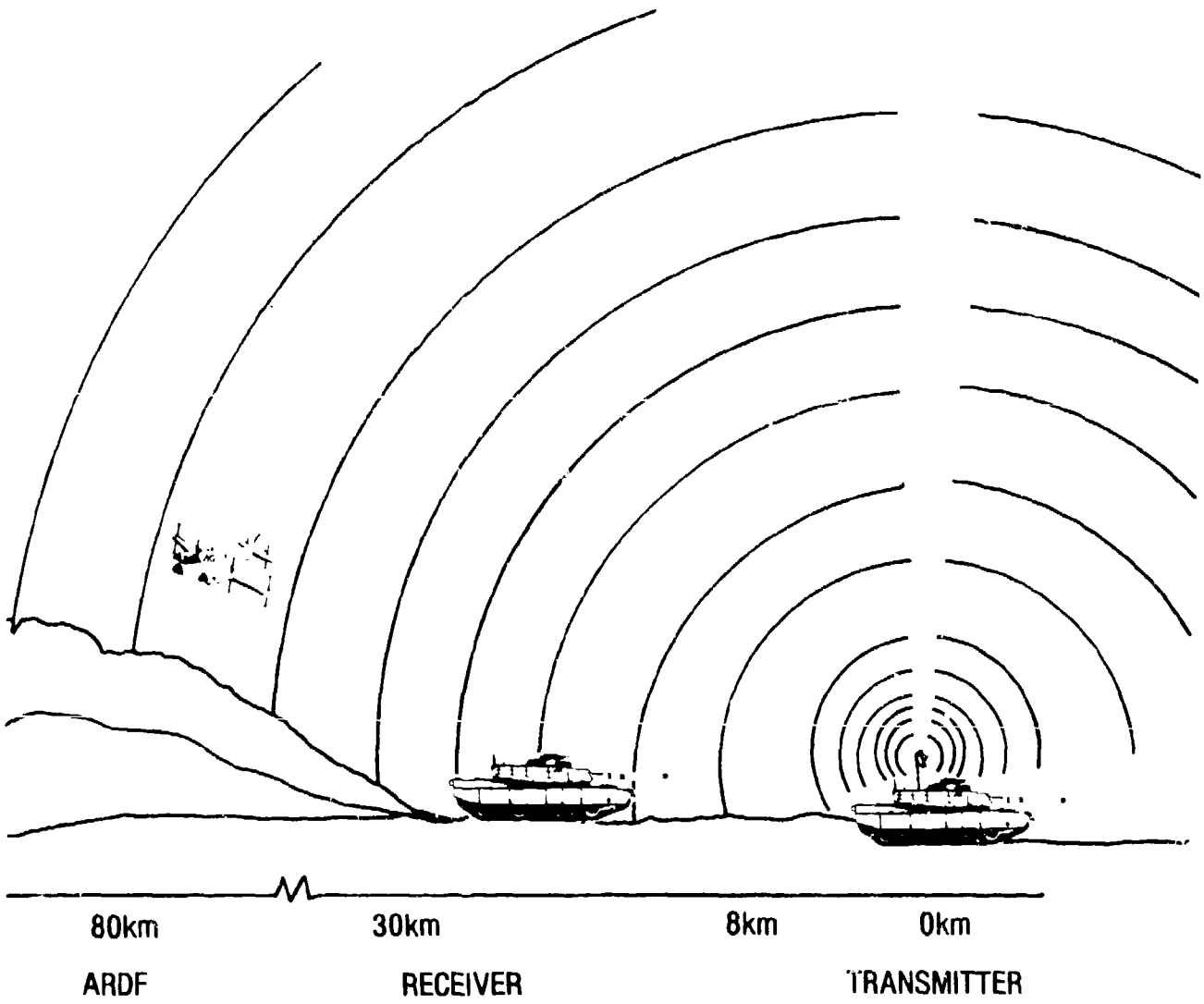
At a range from ten to 100 kms, and at an altitude from 3,000 to 5,000 feet, an ARDF aircraft can sweep a front from five to 300 kms wide, and up to 50 kilometers deep. When an ARDF aircraft is kept 30 kms or more from the FEBA by suppressive fires, the ARDF target area may be larger. However, when the area is larger, the number of VHF targets emitters on the same frequency within the area is probably too large to discern effectively.

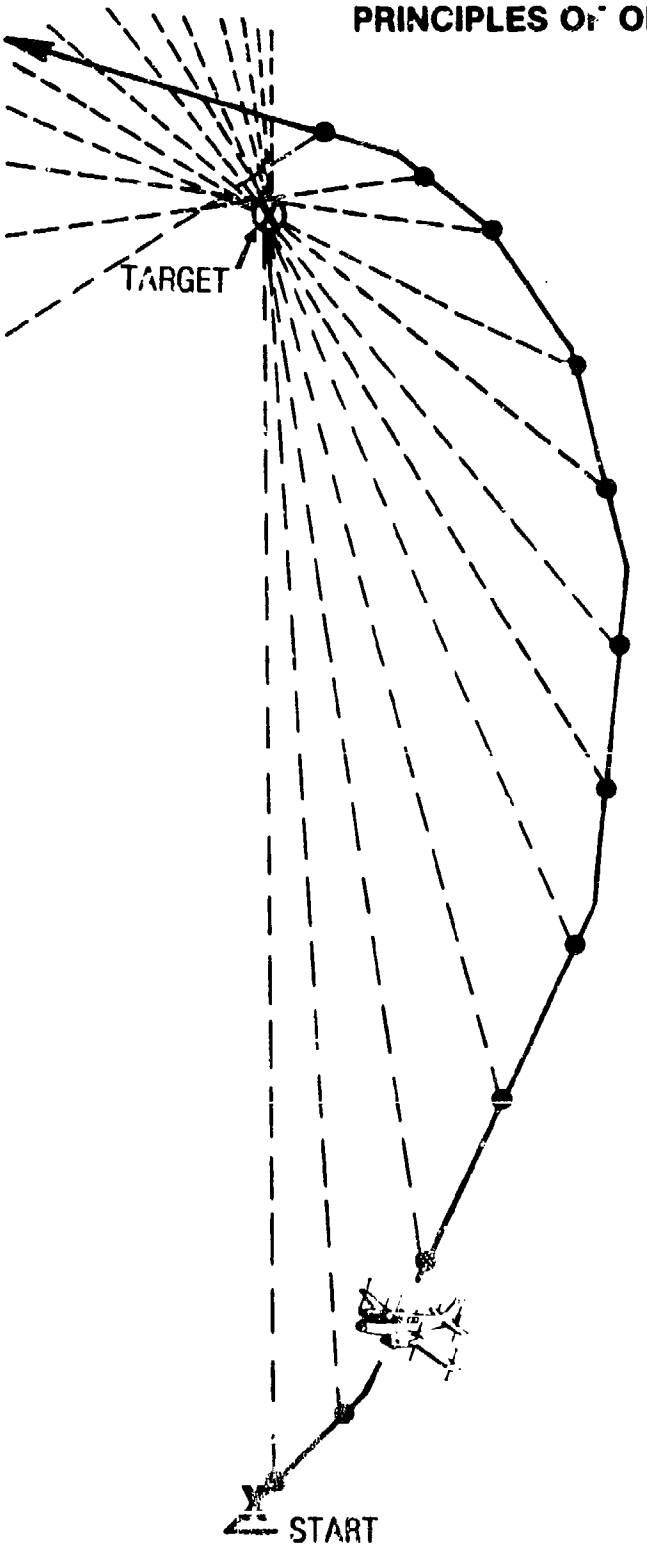
High Frequency ARDF. **A simple radio transmitting antenna radiates waves in many directions, although the strength of the waves may be greater in certain directions and at certain angles above the ground. Both the skywave and groundwave may be used in HF communications. Long distance HF radio transmissions operate principally by means of skywaves refracted from the ionosphere to a receiving antenna on the earth's surface. HF airborne direction finding operations are conducted against these intentional and unintentional skywaves, *prior to refraction.***



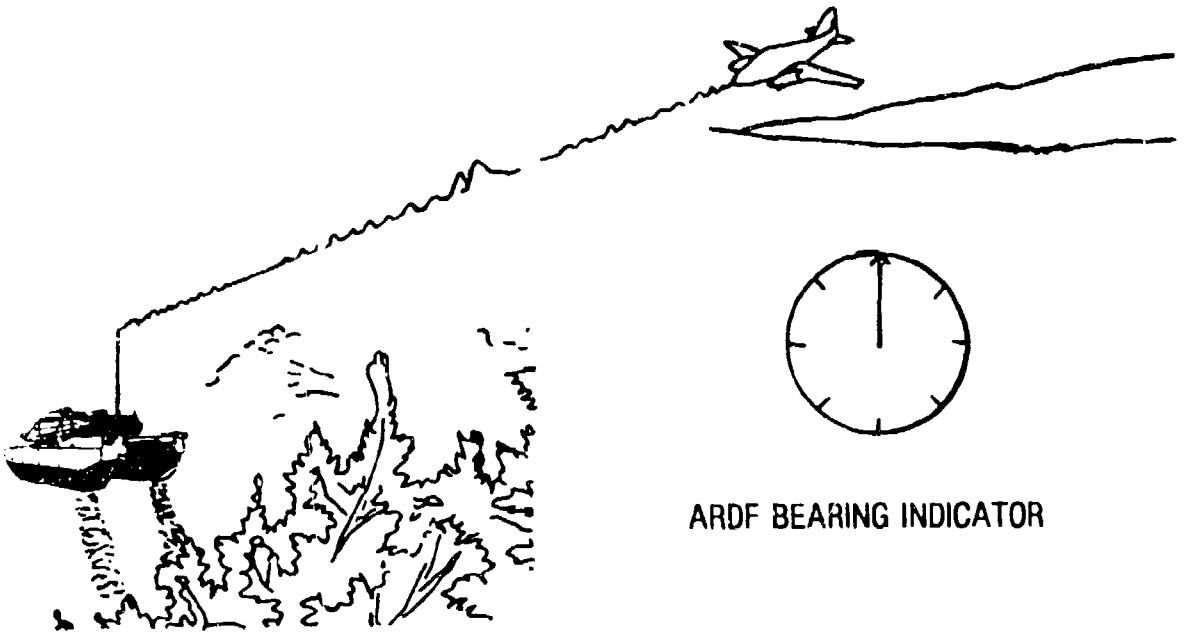
In short distance HF radio transmissions, the groundwave rather than the skywave is the principal means of communications. However, airborne DF is conducted against t' unintentional by-product (skywave) of this type transmission. The distance from the transmitter at which these waves can be received by ARDF is affected by transmitter output power, antenna type, terrain, and operating frequency. Eight kilometers is a typical distance. Although frequency affects wave propagation, the manner in which airborne DF operations are conducted against HF and VHF targets remains unchanged.

Very High Frequency ARDF. **The energy from a VHF transmitting antenna is normally radiated as an omnidirectional wave through the atmosphere to a receiving antenna located within line-of-sight. Airborne equipment, because of greater elevation, is capable of intercepting this line-of-sight transmission at a greater distance, enhancing its operations at an extended range.**



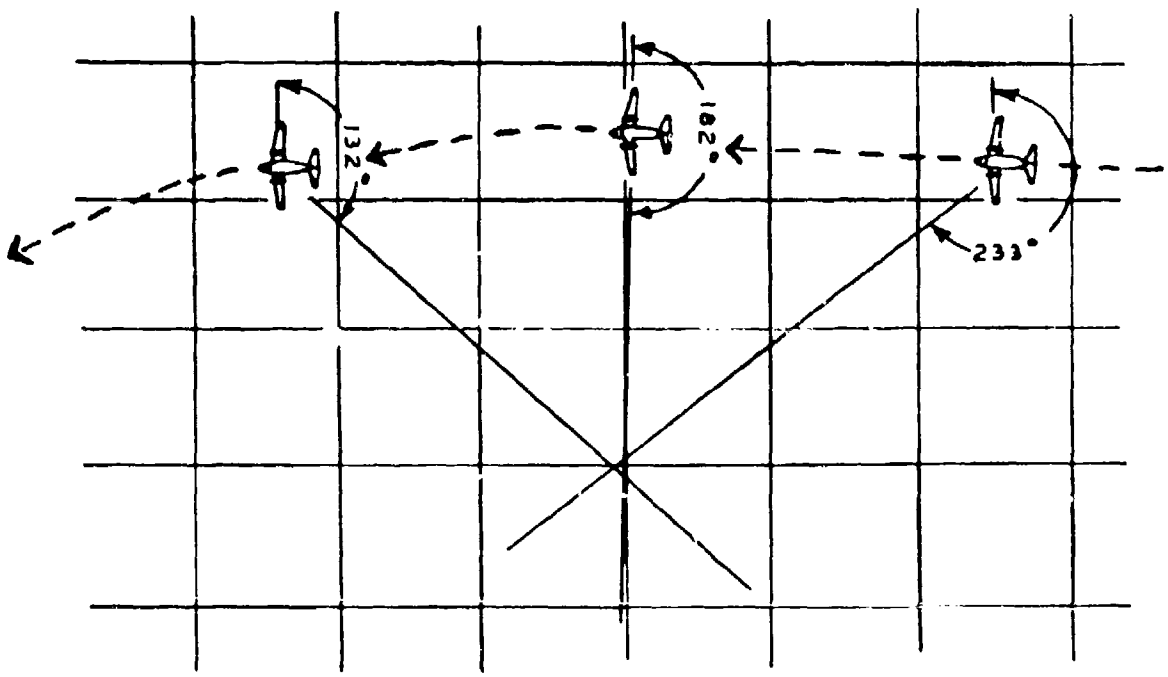


The establishment of a suitable base line is affected by tactical, strategic, and technical considerations. In DF operations, a base line is identified as the line or axis along which lines of bearing are taken. It may be straight or curved, depending upon a technically acceptable environment and the area to be covered.

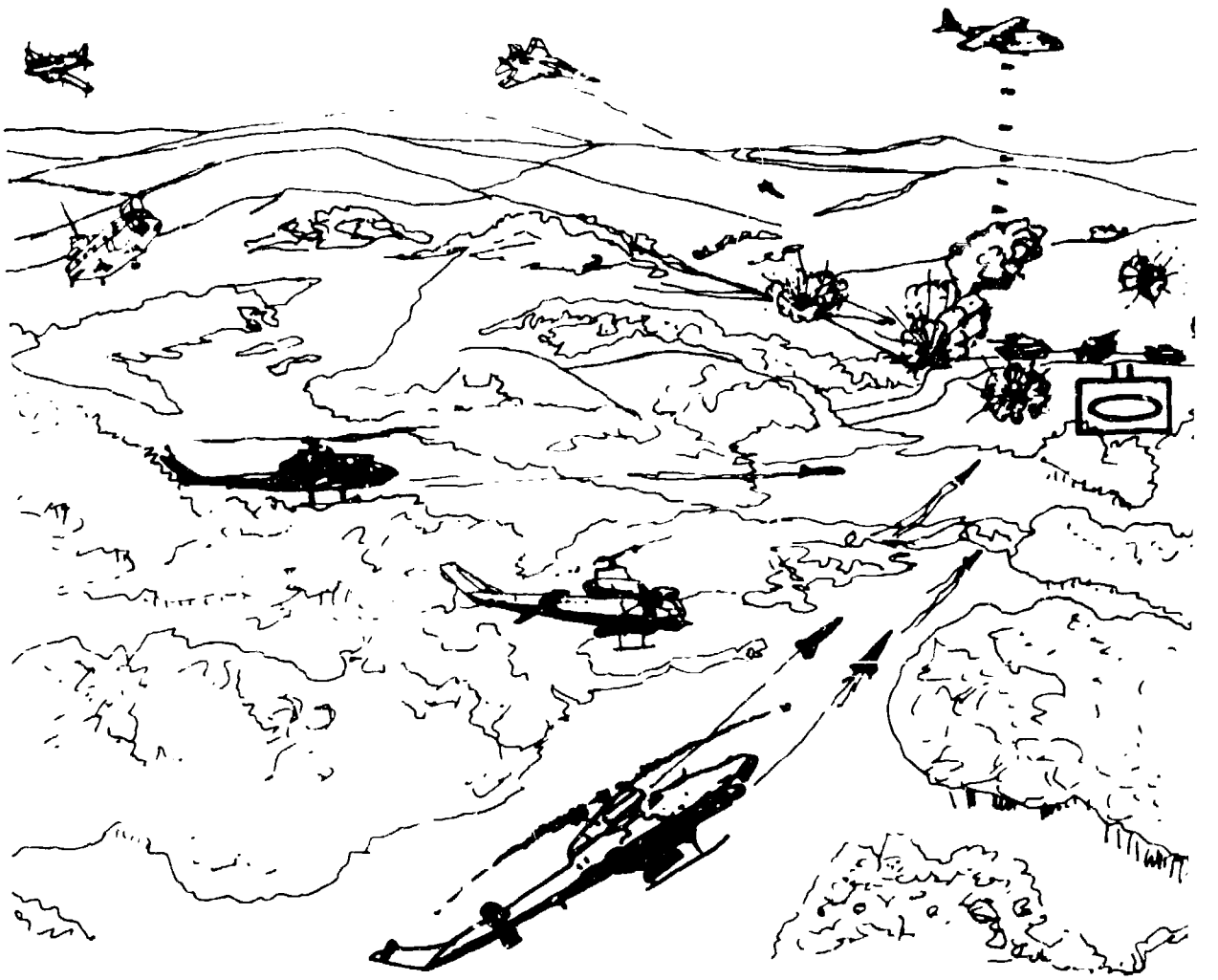


ARDF BEARING INDICATOR

After energy has been received by the antenna, passed through the coupling system, amplified, and detected by the receiver, the bearing indicator translates this energy into an intelligible form from which the operator can determine the direction of the arriving signal. Bearings are plotted to determine the location of the transmitting antenna.



ARDF provides the tactical commander with approximate location of hostile emitters for subsequent destruction, deception, or continued observation for EW/intelligence exploitation.



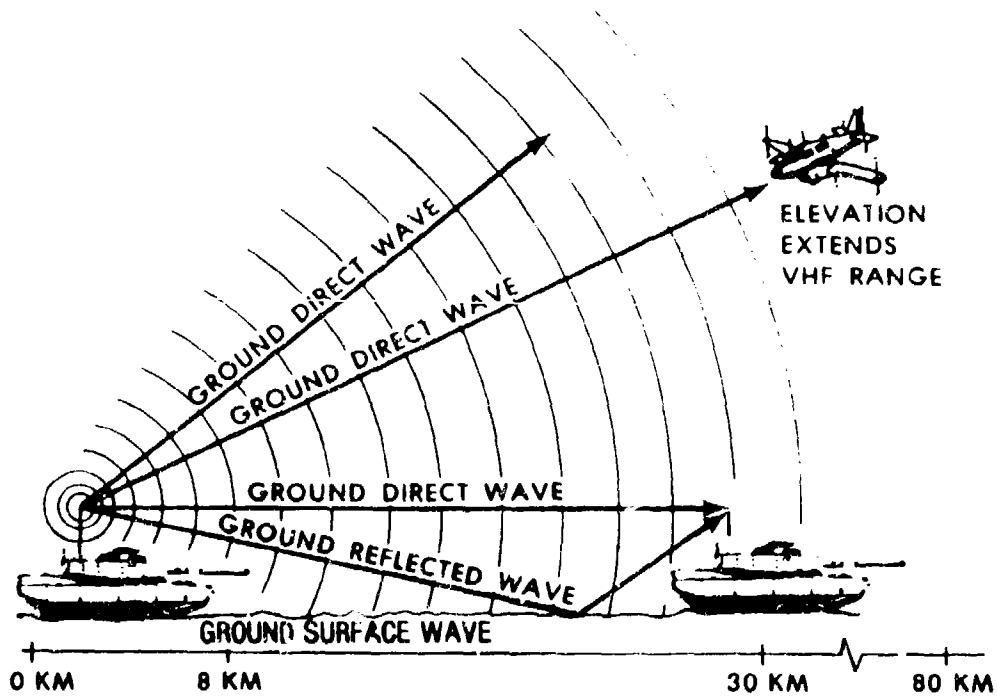
The basic method of DF plotting is the measurement, at a receiving or centralized plotting station, of the angle between a predetermined reference line (usually magnetic or true north), from a known point, and the direction of travel of the electromagnetic waves arriving from a distant transmitting station. The results are then plotted on a map and the point of intersection is the target's probable location.

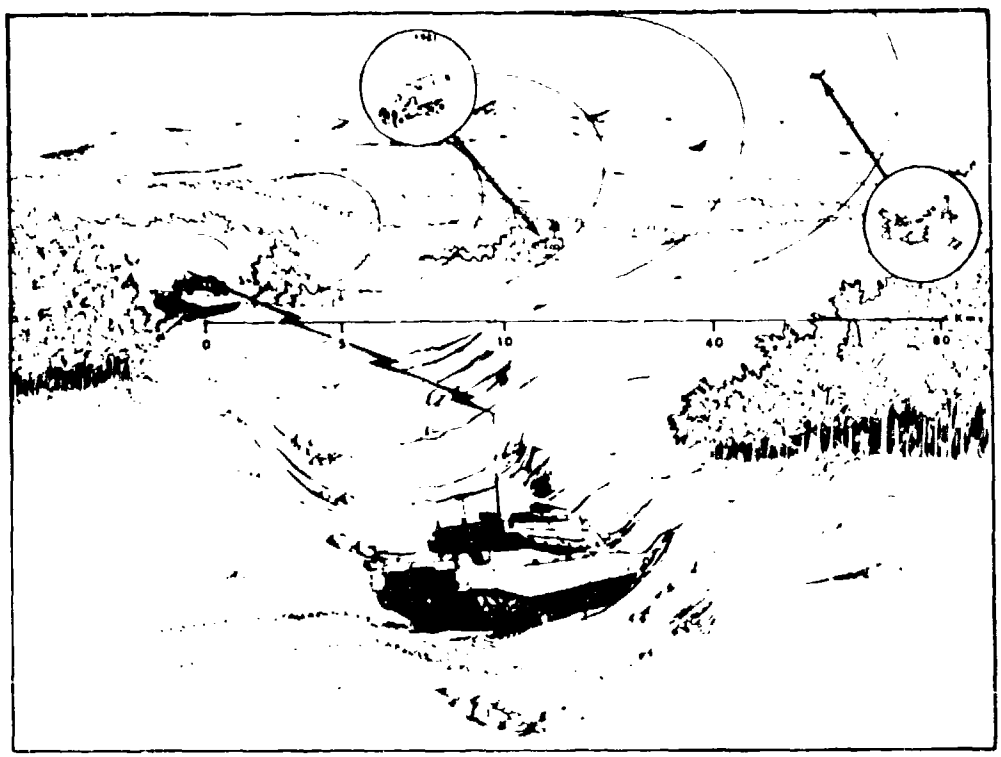
SECTION VI

VHF DIRECTION FINDING ACCURACY

The VHF range (30 to 300 MHz) is used by most tactical radios. This is a simple explanation to describe how RDF functions; its accuracy is determined with respect to VHF radios. A radio transmits and receives energy (radio waves). VHF radio waves travel from the transmitter to a receiver by the groundwave which travels directly to, or is reflected by, the transmitter to the distant receiver through or above the soil or sea. VHF communications are predominantly short range, line-of-sight, FM voice and use omnidirectional vertically polarized antennas.

VHF RDF depends on the effective radiated power (ERP) and the antenna directivity of the target emitter to provide a strong groundwave which may be targeted by RDF. RDF is effective when equipment is compatible with the modulation, frequency, and bandwidth of the signal transmitter.





Ground station RDF systems can determine approximate locations of VHF transmitters at ranges from 0 to 40 kms or more. Airborne platforms can extend the range of RDF to 80 kms or more.

DIRECTION FINDING
TARGET LOCATION ERROR

Direction finding accuracy is determined by the power and antenna directivity of the target transmitter; by electromagnetic influences which affect radio wave propagation; and by the capability of direction finding equipment and operations. Because rather complicated mathematical formulas are applied to determine the effect of these influences, RDF accuracy was previously expressed for tactical use with respect to rules of probability and standard deviation as an equivalent circular error probability (CEP).

A CEP is the radius of a circle within which a given percentage, usually 50 percent, of the projectiles is expected to fall. The term CEP is most popular as an artillery term and is used to explain the delivery accuracy of a weapon system. Because most tactical requirements for RDF have, in the past, been satisfied by the CEP report, it is now used to indicate the target location error of direction finding.

The intersection of three or more RDF bearings actually provides an elliptic pattern; a CEP is deduced by reporting the length of half or two-thirds of the major axis of the ellipse. The resulting CEP provides a mathematically crude, but adequate location. A CEP by itself does not provide targets.

The development and construction of a CEP is complicated but targeting analysts should understand the model.

Fifty percent or 66 percent of the length of the major axis of the ellipse is used as the radius of a CEP. As DF improves, some tactical units are now using 66 percent of the length of the major axis as the radius of the CEP.

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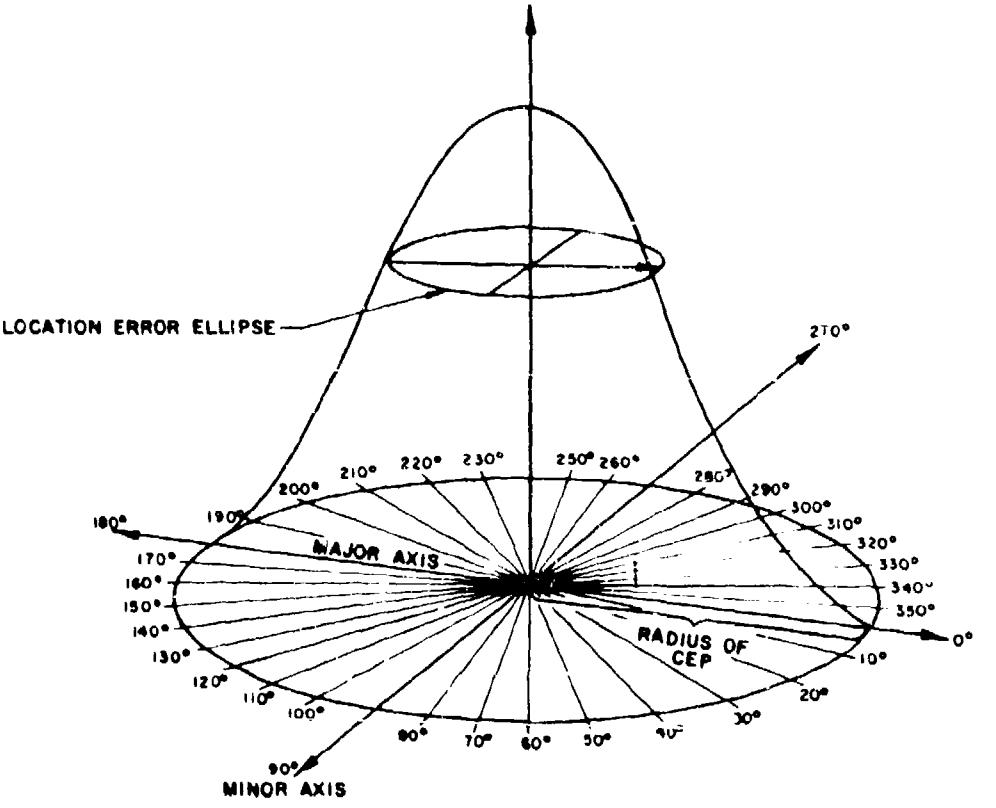
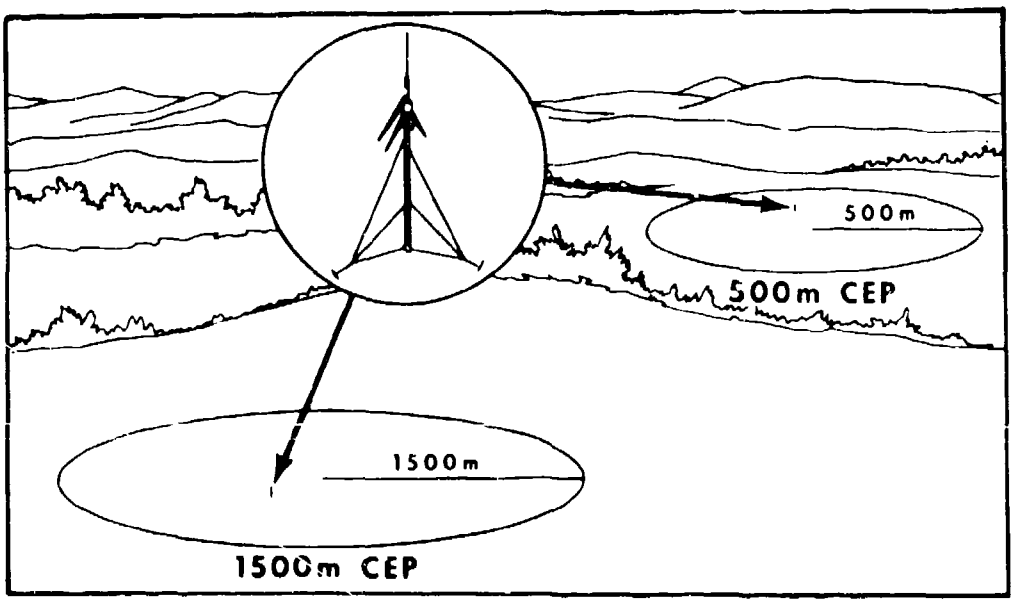


The diagram, when simplified, illustrates the following:

(1) The length of the major (largest axis);
(2) The length of the minor (shortest) axis; and,
(3) The orientation of the major axis with respect to location e.g., true north).

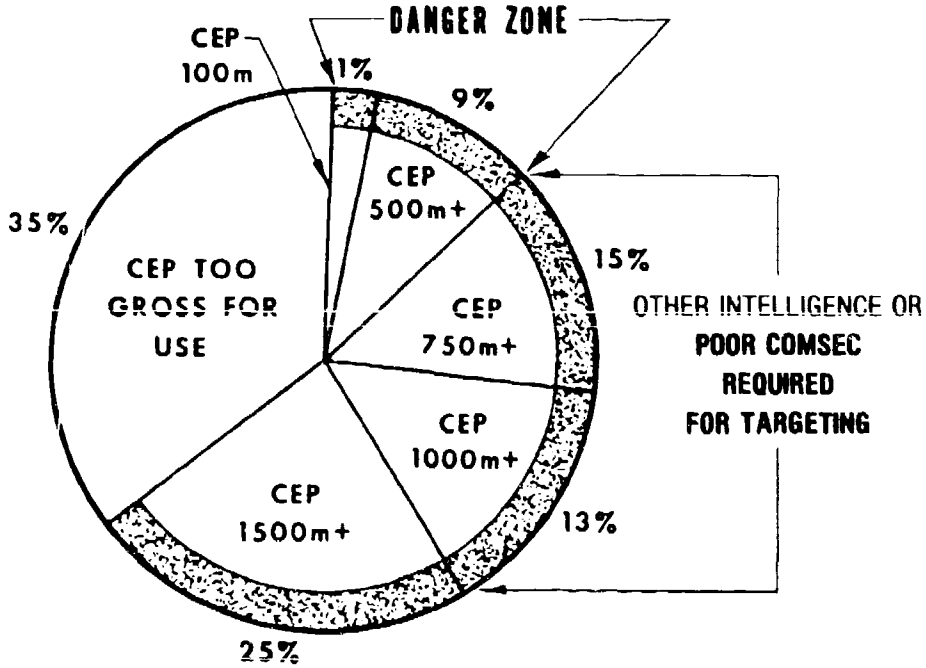
The equivalent CEP is determined by using one-half or two-thirds of the length of the major axis to form the radius of the circle. Using a CEP instead of an ellipse, we are now reporting the location of an emitter inside of a circle instead of inside an "egg." The radius of the circle begins on the best probable location determined by the ellipse and extends outward to form a circumference related to the degree of probability. The user should always inquire as to the probability factor of the CEP if it is not provided by the direction finding unit. Target analysts should also be able to plot the more accurate RDF ellipse. However, a computer is required to provide RDF ellipse reports; manual systems cannot provide this capability. As a result, most tactical RDF data are reported as a CEP.



When a 500-meter CEP is reported with a 90 percent probability, there is a 90 percent chance that the target transmitter is located somewhere within a 500-meter radius of the circle. The circle with a radius of 500 meters contains 785,000 square meters or about 3/4 of a square kilometer. By comparison, a battalion size command post's antenna array typically occupies about 10,000 square meters. A single FM/VHF ground plane antenna occupies about nine square meters.

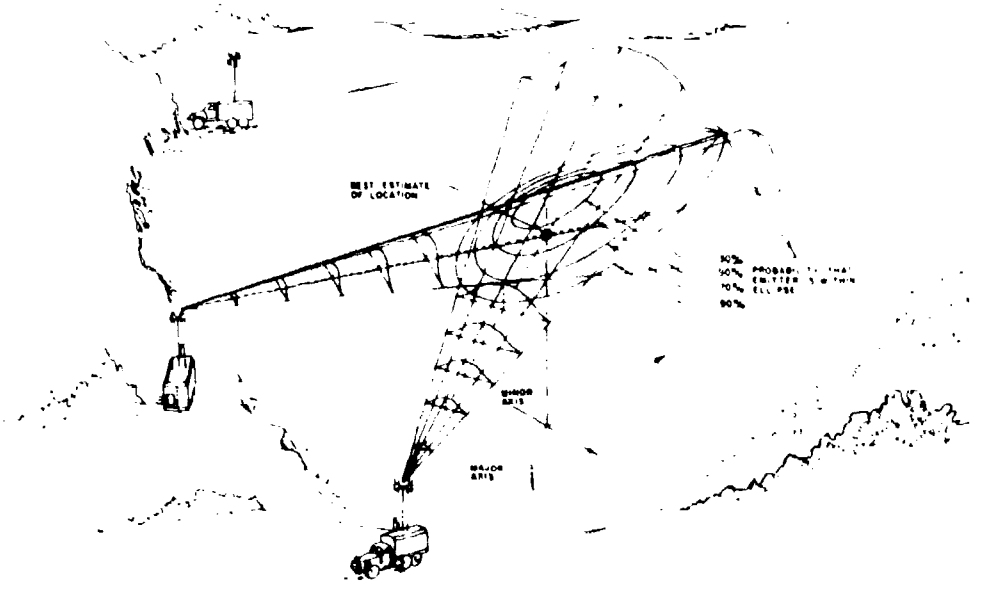
If the CEP is increased to 1,500 meters (a more typical RDF accuracy in tactical situations), the circle will contain 7,065,000 square meters or about seven square kilometers in which to locate a 10,000 square meter antenna array or a single antenna occupying nine square meters. That information by itself is only of marginal value in the acquisition of targets. But! Most enemy SIGINT analysts apply that information in conjunction with poor SIGSEC on our part, with terrain analysis, and with predictions of radio operator behavior (signal units consistently use ideal communicating locations) to provide targets. DF may provide the master clue!

Tactial RDF accuracy may be measured in meters of CEP. Experience indicates that an RDF accuracy of 500 meters CEP is considered to be a very good RDF fix. Probably less than ten percent of all RDF fixes (on 100 different transmitters) will be reported with an accuracy of 500 meters CEP.



Percentile Graph of Typical RDF Fixes Reported as CEP at a Range from Transmitter to RDF Station of less Than 30 Km

MODEL OF ELLIPTIC ERROR PROBABLE



TWO STATION DF BEARING ERROR ELLIPSE

With the advent of computer-assisted RDF, the user of the RDF product should become aware of how an elliptic error probability (EEP) is derived and how to use its ellipse. When plotted, an EEP provides a more accurate location than does a CEP.

If one could actually see radio wave propagation, it would appear in a manner similar to the illustration. The RDF bearings form an ellipse. Usually three or more bearings are used to determine an RDF fix, but only two RDF stations are shown in the above illustration to reduce diagram clutter.

WHAT CAUSES RDF ERRORS?

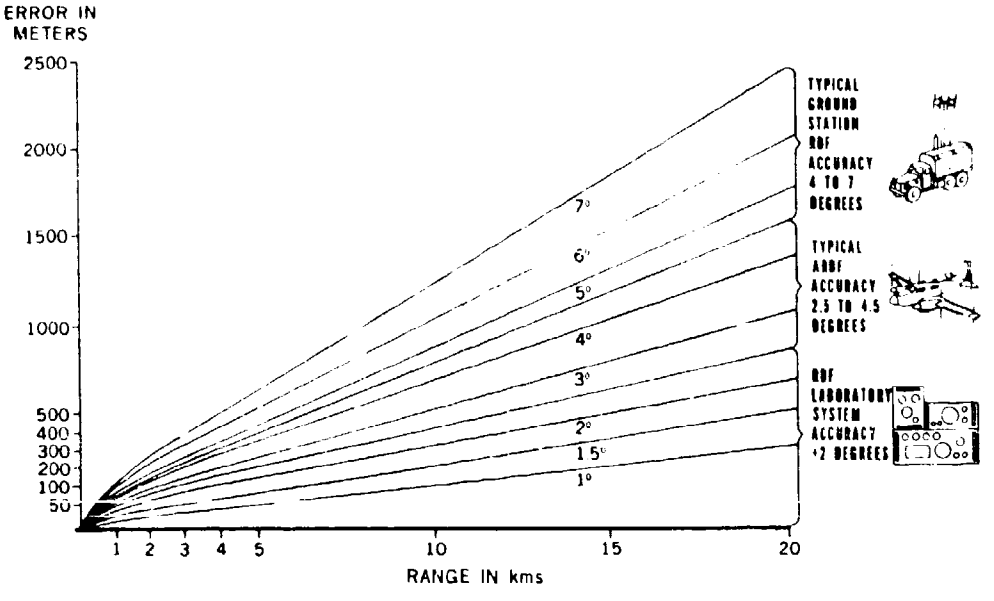
There are three main causes of RDF error: radio wave propagation irregularity; RDF and emitter equipment inconsistencies; and RDF operator mistakes. The key words are *system accuracy* and *operational accuracy* of RDF. *System accuracy* is evaluated in an electronics laboratory, where equipment is unaffected by environmental or human factors. It is system accuracy that is usually reported in equipment manuals and threat documents. System accuracy provides a source of comparison, but should not be used to predict the accuracy of target acquisition. *Operational security,* on the other hand, is field accuracy — the results obtained by experience during training exercises or combat. Let us examine, in general terms, the principal causes of RDF error and their effect on RDF accuracy.

Radio Wave Propagation Irregularity.

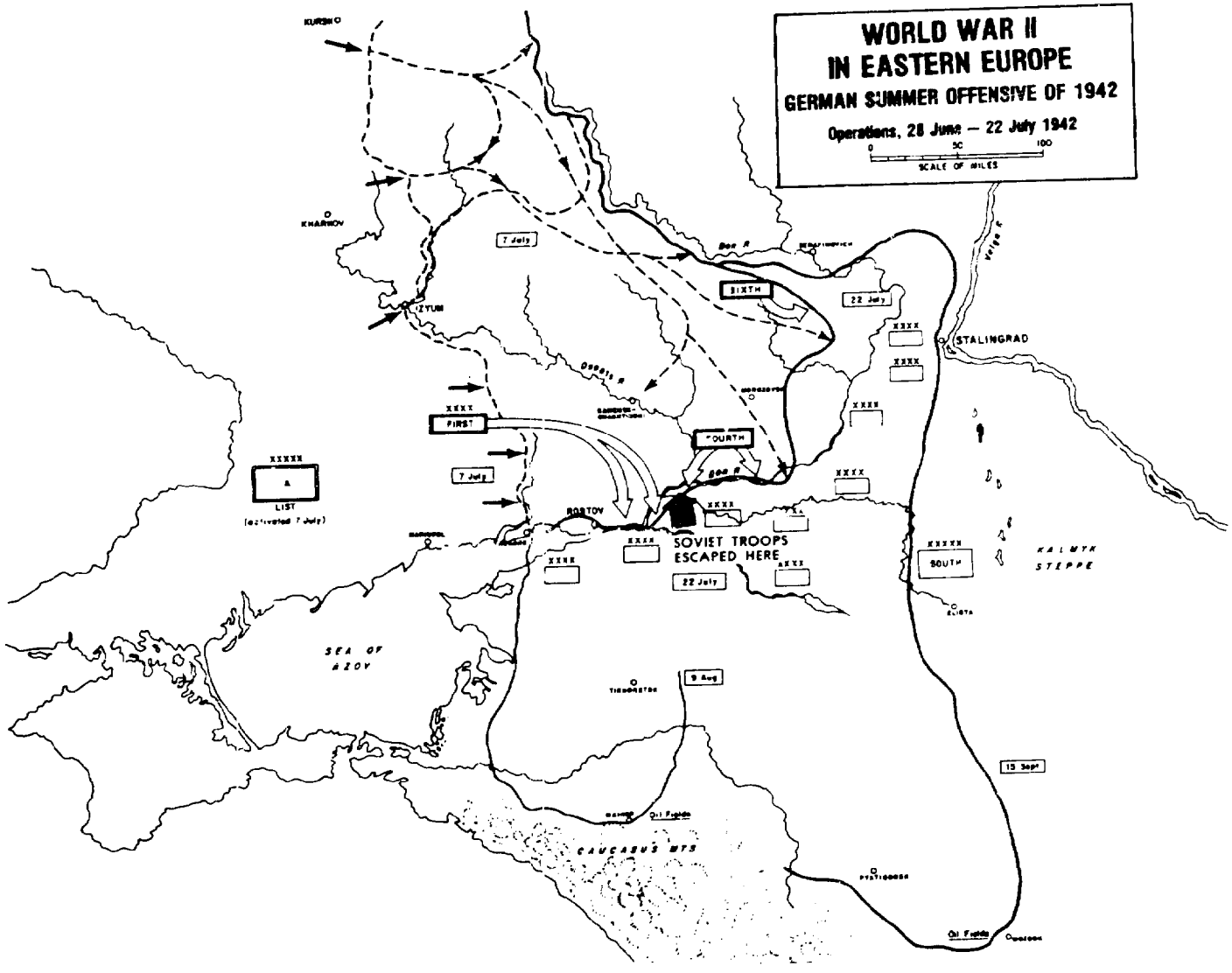
One example of radio wave propagation effect is the multipath error which occurs when a radio wave produces both a reflective and an instant component wave, each arriving at different times and which may appear out of phase. The direction finding station has difficulty determining the true signal. Where the received signal arrives from two or more paths, the RDF operator will read an azimuth that is in error and biased. Errors up to ten degrees can result from such a condition. The VHF multipath error is caused by other equipment located near the RDF equipment, by man-made obstructions, or by terrain which may distort the path of the signal. Multipath error occurs more frequently at VHF than HF since a smaller area can act as a reflector to a VHF signal. This is important because when VHF radio operators deliberately place terrain obstacles to radio wave propagation between the intended receiver and the enemy RDF, they take advantage of the potential effect of multipath error. This technique is called "masking." (More about masking in Section VIII.)

RDF Equipment Errors.

Tactical RDF equipment is designed to perform with a system accuracy within plus or minus two degrees. Accuracy within plus or minus two degrees is the same as a total error of four degrees with regard to system plotting. The key words reported in threat manuals are *system accuracy.* The *operational accuracy,* also referred to as field accuracy, of enemy tactical RDF equipment is usually within plus or minus 3.5 degrees (total 0 to 7 degrees).



Strategic or semi-permanent RDF equipment, usually targeted at HF communications and located well behind the FLOT is usually not more accurate than plus or minus two degrees; but the greater distance between the target transmitter and the RDF site results in larger linear error and in a CEP in excess of 20 kilometers (closer to 50 kilometers). Nevertheless, strategic RDF plays an important role in detecting major troop movements. The Soviets probably used strategic RDF and communications intelligence (COMINT) to detect a temporary gap between the German Fourth and Sixth Panzer Armies confronting Stalingrad on 13 July 1942, allowing two-thirds of the Soviet forces trapped across the Don River to escape — a significant factor in the eventual Soviet victory at Stalingrad.


WORLD WAR II
IN EASTERN EUROPE
GERMAN SUMMER OFFENSIVE OF 1942
Operations, 28 June – 22 July 1942
SCALE OF MILES
KHARKOV
IZYUM
7 July
SIXTH
22 July
STALINGRAD
FIRST
FOURTH
7 July
XXXXX
A
LIST
(activated 7 July)
ROSTOV
SOVIET TROOPS
ESCAPED HERE
22 July
SOUTH
KALMYK
STEPPE
SEA OF
AZOV
9 Aug
15 Sept
CAUCASUS MTS
Oil Fields
Oil Fields

RDF equipment operators can also contribute considerable error to RDF equipment by making even minor mistakes in many operational and land navigational functions for which they are responsible. Additionally, tactical RDF equipment can seldom be verified, or operator error distinguished from equipment or propagation error. This is important because RDF is susceptible to deception.

Deception Operations Against RDF.

RDF data enable analysts to determine the approximate location of an active transmitter whose signal has been intercepted and from which RDF bearings were taken. RDF bearings in themselves do not provide sufficient information to correctly identify the transmitter. Identification is usually provided through analysis of signals. If enemy SIGINT analysts are deceived into believing that a specific transmitter is assigned to a division tactical command post, RDF may reinforce that conclusion. This is especially true if RDF reports that the transmitter is indeed located where a division command post should be located with respect to the FLOT and other boundaries. Other deceptive techniques against reconnaissance, to include decoy equipment and installations, would further reinforce the deception. By contrast, an otherwise flawless deception plan not supported by electronic deception could be detected easily by RDF. It can be argued that deception is not truly an error attributable to RDF, but to the conclusions drawn from RDF. That point is not contested.

The use of speech security equipment (NESTOR or VINSON) with VFH radios does not provide protection against DF. Speech security devices prevent clear text revelation of unit identity or call sign identity; but, if only command and control nets use those devices, then the identification of key emitters by RDF can still be accomplished. In fact, when only key command and control nets within a unit use speech security equipment, this practice greatly assists enemy RDF operators in identifying command post transmitters.

SECTION VII

THE THREAT

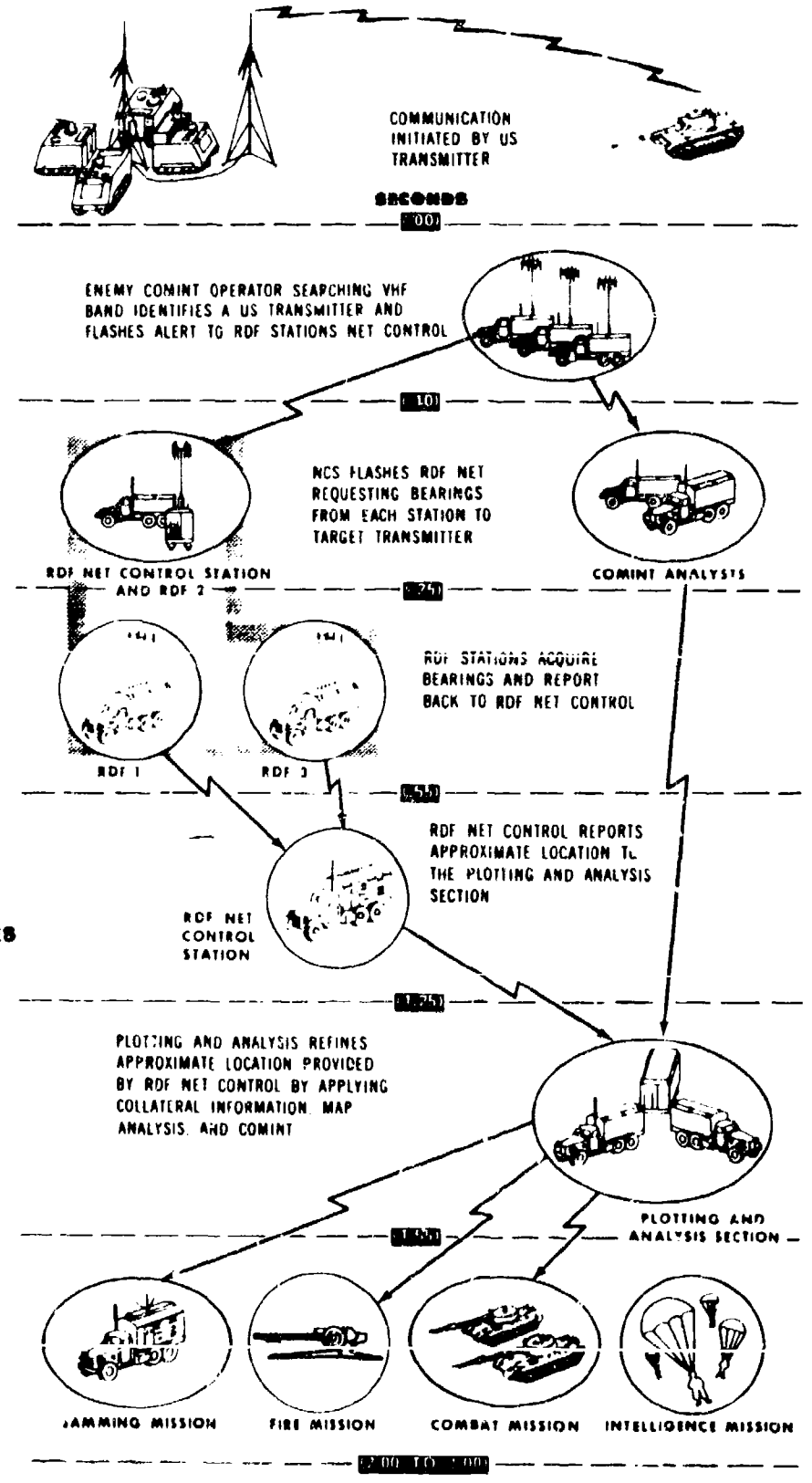
TACTICAL DF EFFECTIVENESS OF THREAT FORCES

Tactical DF is effective. It is a threat. DF is effective because large numbers of RDF equipments are integrated and employed in conjunction with other intelligence to locate US Army and NATO emitters. DF is also used by the enemy to identify the control or weapon systems with which these emitters are associated. DF is used chiefly as an analytic aid to detect unit groupings and movements, and to sort out communications systems. It also provides clues as to where friendly forces are *not* located. However, when our forces provide lucrative SIGINT because of poor SIGSEC practices, the enemy forces may be able to actually depend upon DF to exploit the weakness and provide targeting data for suppressive fires; or if that fails, to direct their jammers more accurately. Poor SIGSEC makes DF very effective.

While ground force intercept and DF equipment is not always highly sophisticated, there is a lot of it and it is located very near the FLOT.

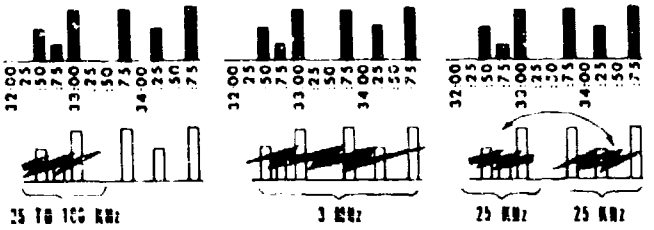
THIS IS HOW A RADIO DIRECTION FINDING NET WORKS

About 25 seconds after the communication began, the enemy targeting sequence can continue even if friendly communications are terminated. This is the danger point — communications longer than 20 to 25 seconds. Of course, this is meant to depict an optimum sequence of events, and is illustrated for training purposes only. THIS DOES NOT REFLECT AN ACTUAL CAPABILITY


COMMUNICATION INITIATED BY US TRANSMITTER
SECONDS
:00
ENEMY COMINT OPERATOR SEARCHING VHF BAND IDENTIFIES A US TRANSMITTER AND FLASHES ALERT TO RDF STATIONS NET CONTROL
:10
NCS FLASHES RDF NET REQUESTING BEARINGS FROM EACH STATION TO TARGET TRANSMITTER
RDF NET CONTROL STATION AND RDF 2
COMINT ANALYSIS
:20
RDF STATIONS ACQUIRE BEARINGS AND REPORT BACK TO RDF NET CONTROL
RDF 1
RDF 3
:50
RDF NET CONTROL REPORTS APPROXIMATE LOCATION TO THE PLOTTING AND ANALYSIS SECTION
RDF NET CONTROL STATION
1:20
PLOTTING AND ANALYSIS REFINES APPROXIMATE LOCATION PROVIDED BY RDF NET CONTROL BY APPLYING COLLATERAL INFORMATION, MAP ANALYSIS, AND COMINT
PLOTTING AND ANALYSIS SECTION
1:50
JAMMING MISSION
FIRE MISSION
COMBAT MISSION
INTELLIGENCE MISSION
2:00 TO :00

EFFECTIVE RADIO DIRECTION FINDING SUPPORTS EFFECTIVE RADIO JAMMING

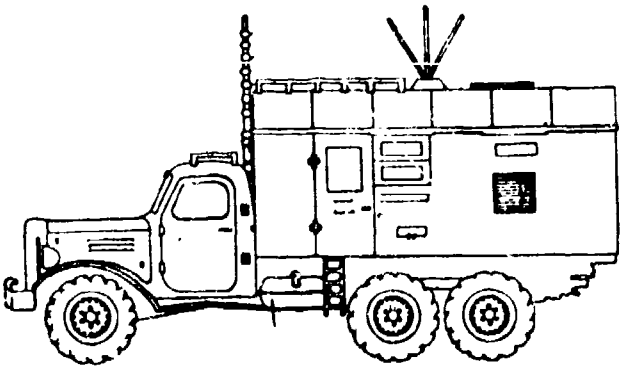
Efficient jamming depends on direction finding to analytically select and precisely locate target transmitters. The receiving element of the target transmitter is then selected for jamming, and the jammer's antenna oriented to the location reported by RDF. ***Soviet doctrine establishes a requirement to jam US Army command control, and weapon system communications when they cannot be destroyed by suppressive artillery fires.*** The three main types of jamming are illustrated below. Enemy forces jam VHF, but they also depend on VHF for their own command, control, and weapon systems. One way they are able to control this problem is using VHF directional antennas which have a greater effective radiated power (ERP) for their own communications. They practice this technique in training. The Soviet type force use VHF and UHF multichannel communications at selected key levels and employ HF tactical communications as a redundant communications system down to tank platoon level.



SPOT JAMMING BARRAGE JAMMING SWEEP JAMMING

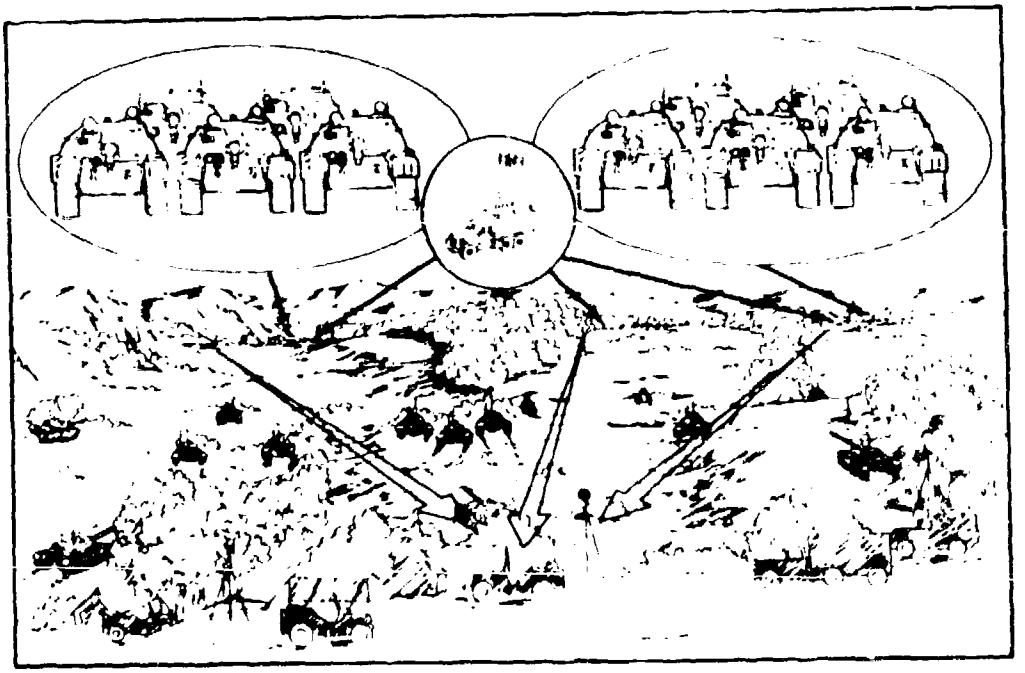
Three Methods of Communications Jamming

Jamming can also support DF by jamming a target for a prolonged period and causing the target station to backlog traffic. When the jamming is terminated, the target station may then transmit continuously over a long period to relieve the backlog of traffic. Prolonged transmission in these cases enables DF to refine numerous bearings obtained during the long transmit time.



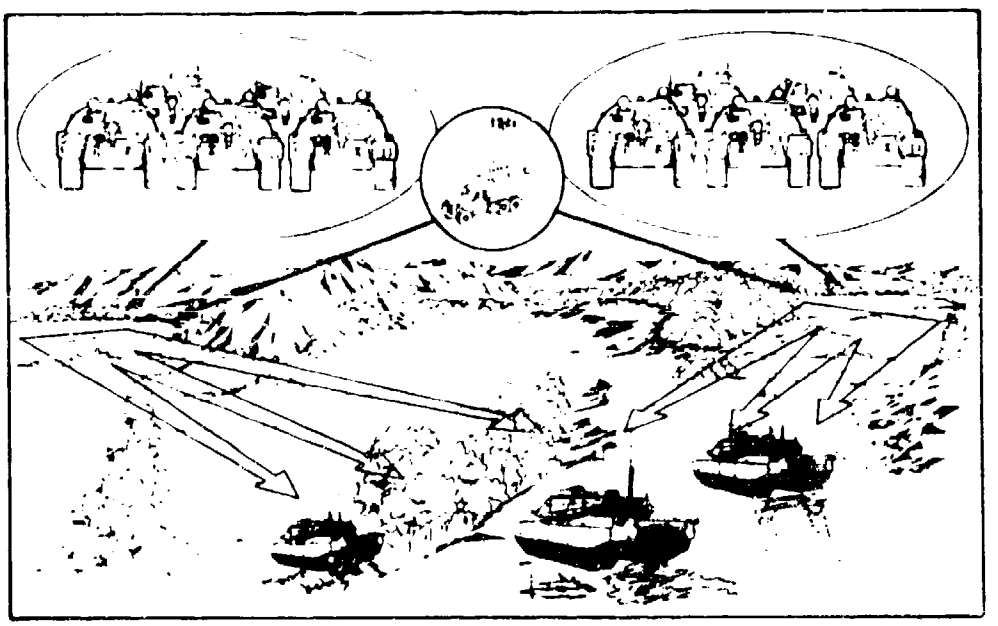
DIRECTION FINDING AND TACTICS ON THE MODERN BATTLEFIELD

The use of direction finding is a tactical consideration; it is part of EW tactics. Enemy forces are confronted with two tactical choices pertaining to the employment of ground station RDF. If the enemy commander's objective is to obtain the best bearing to tactical transmitters within a compact, narrow, division area of the FEBA, he would most likely locate his RDF positions on a straight or concave baseline to provide the best azimuth angles at short ranges within 20 kms, and fair angles at longer ranges to 75 kms. This is one indication of a possible penetration attempt by enemy forces. Similarly, if friendly RDF elements are properly aware of basic command plans they can deploy to provide the most effective support.



EXPECTED RDF TARGET AREA
FOR ENEMY BREAKTHROUGH OPERATIONS

If the enemy division commander's objective is to obtain the best bearings over a wide flanking area, he would most likely locate his RDF positions in a triangular or quadrilateral base pattern which provides fair azimuth angles on most transmitters at the expense of more accurate angles on transmitters within short range. This is one indication of a flanking attack. Surveillance techniques which may reveal these employments should be considered as basic intelligence requirements along with other indications of enemy intentions.

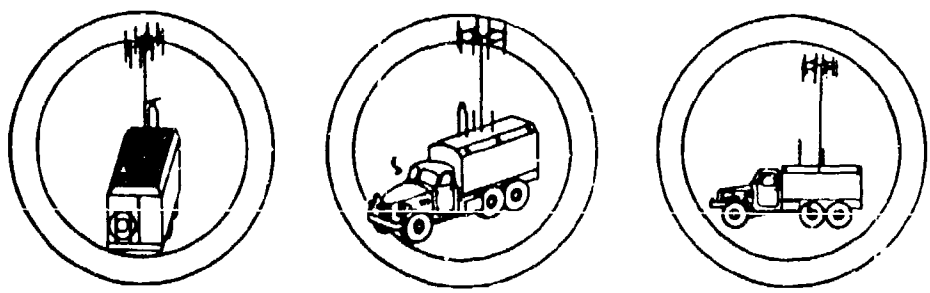


EXPECTED RDF TARGET AREA
FOR ENEMY FLANKING ATTACK

Before exploring the solution to this threat with the use of horizontally polarized directional antennas, let's look at the enemy's RDF antenna characteristics.

THE ADCOCK RDF ANTENNA

The Adcock RDF antennas usually consist of from two to eight spaced vertical antennas connected in opposition. There are other variations, but the illustration shown below is typical. It is most efficient against the vertically polarized component of an incoming radio wave. The Adcock antenna is especially reliable for VHF signals at a point beyond strong ground wave range (e.g., in an area to the rear of the FEBA). As a result, when the vertically polarized component of a radio wave predominates, as is presently the case with US Army tactical communications using omnidirectional antennas, the Adcock antenna is very effective and has little if any polarization error. *Its chief weakness is its limited effectiveness in detecting horizontally polarized antennas.* In addition, the Adcock antenna and its connecting cables are comparatively complicated to adjust. The Adcock direction finder is not a first choice for a multi-polarization tactical device. Good calibration of the Adcock at a new site is very difficult and is seriously affected by changing weather conditions. Nevertheless, the Adcock type antenna remains more than adequate for enemy forces so long as the US Army relies heavily on vertically polarized, omnidirectional, VHF antennas for tactical communications.

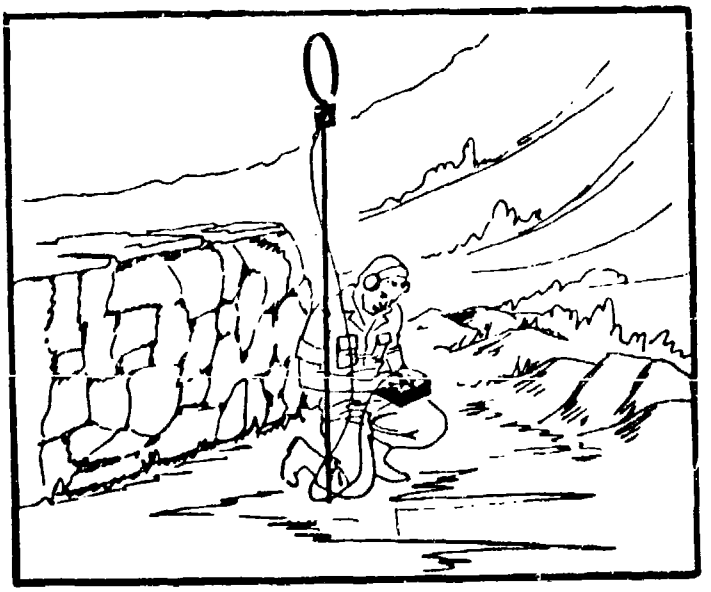


TOP VIEW FRONT VIEW SIDE VIEW

LOOP ANTENNAS

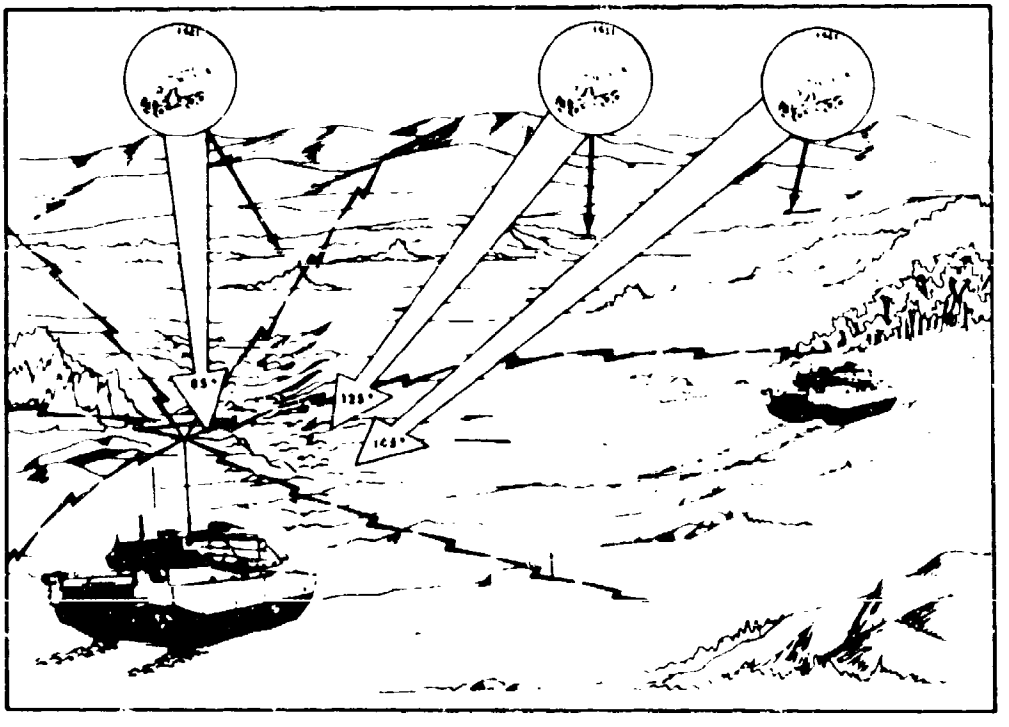
Enemy forces may also use spaced loop, rotatable loop, and other loop type tactical VHF direction finding antennas. Like the Adcock, the spaced loop is a vertically polarized antenna made up of two parallel loops fixed coaxially to the ends of a rotatable boom. Several variations are available and RDF positions of this type may be mobile. The spaced loop antenna is not very suitable for tactical conditions. The position requires considerable installation and calibration time, has poor sensitivity, and bearing ambiguity is difficult to discern. As a result, its accuracy is limited. However, other HF and VHF loop antennas do have tactical application.

A special purpose RDF loop antenna used by US Army Special Forces units is shown below to illustrate the small size which is possible with systems of this type. These man-packed units may be used to detect the general location of transmitters and for that purpose they are highly effective. They are also effective as homing devices.



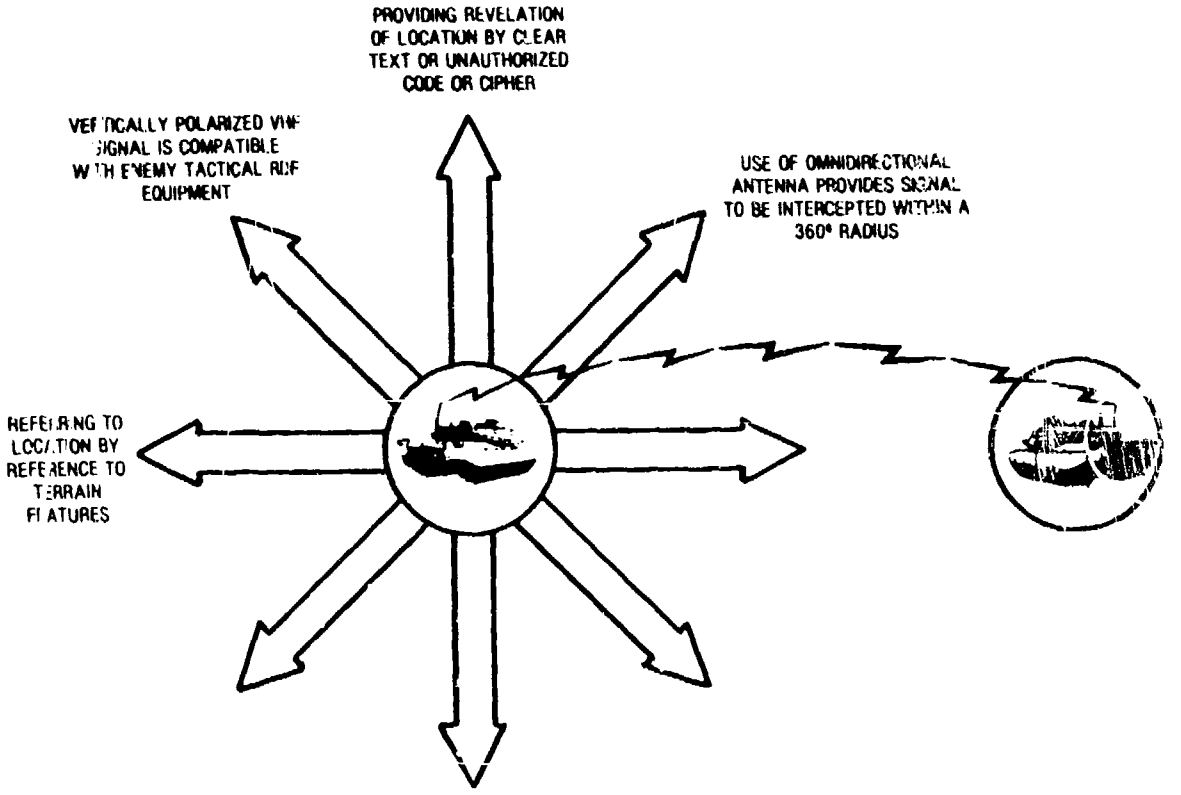
SECTION VIII

HOW TO BEAT RADIO DIRECTION FINDING ALONG WITH THE JAMMING AND ARTILLERY FIRE IT DIRECTS



Once the battle begins and our units are attacking and moving, fast RDF is not a significant threat to fighting units. But when we stop or go into the defense, enemy radio direction finding in conjunction with poor SIGSEC on our part provides targets for suppression — free targets.

During field training exercises, poor COMSEC allows location (by RDF) of many divisional, brigade, battalion, and company command posts with an accuracy (100 to 250 meters) sufficient for target destruction.


PROVIDING REVELATION OF LOCATION BY CLEAR TEXT OR UNAUTHORIZED CODE OR CIPHER
VERTICALLY POLARIZED VHF SIGNAL IS COMPATIBLE WITH ENEMY TACTICAL RDF EQUIPMENT
USE OF OMNIDIRECTIONAL ANTENNA PROVIDES SIGNAL TO BE INTERCEPTED WITHIN A 360° RADIUS
REFERRING TO LOCATION BY REFERENCE TO TERRAIN FEATURES

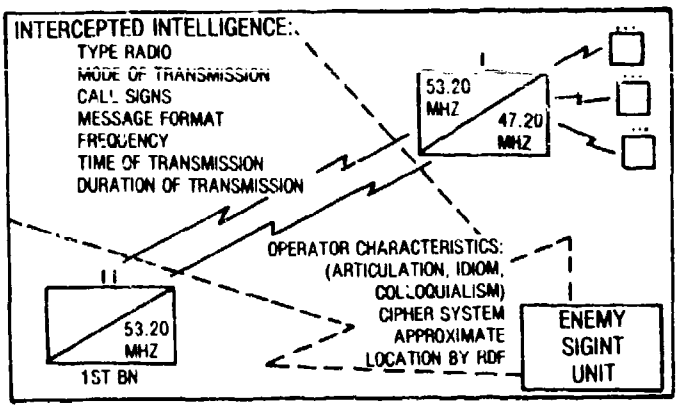
US ARMY RDF TARGETED UNITS MAY NOT BE ABLE TO FIGHT AND WIN UNDER THESE CIRCUMSTANCES

Electronic emitters can be used to identify units, weapons, and command posts because . . .

Unit identity can be simply determined by one or a combination of —

(1) Plain text revelation.
(2) Type transmitter.
(3) Call sign peculiarity.
(4) Analysis of communications traffic.
(5) Transmitter modulation.
(6) Operator identification.
(7) Duration and frequency of messages.
(8) Analysis of unauthorized codes or ciphers.
(9) Misuse of authorized callsigns, codes or ciphers.

ALL OF THIS IS USED IN CONJUNCTION WITH AN ANALYSIS OF THE GENERAL LOCATION OF A UNIT ON THE BATTLEFIELD PROVIDED BY DIRECTION FINDING.



A radio signal provides information even when protected by code or cipher.

Electronic emitters can provide the enemy with the detection, general location, and possible identity of the unit which they serve.

RADIO OPERATORS USING PLAIN TEXT MOST OFTEN REVEAL:

ADA LOCATION

AIRBORNE LAUNCH AREA

AIRHEAD

AIRSTRIKE TARGETS

ASP

ARMOR LOCATION

ASSAULT STRIP

ARTY LOCATION

ARTY TARGETS

AUTHENTICATION FAILURE

AVENUE OR APPROACH

BARRIER LOCATION

BOUNDARY LINE

BRIDGE

CALL SIGN COMPROMISE

CAPABILITY

COMMAND POST

COMMUNICATIONS SITE

CONCENTRATIONS (TROOP)

CONVOY (TIME-LOC)

DEFENSE POSITION

DEPLOYMENT SCHEME

DGZ

DZ/LZ/PZ

EVASION ROUTE

FLOT

FORWARDING STAGING AO

FREQUENCY COMPROMISE

FSCL

GOPL

HELI PAD

LRRP (LOC-ROUTE)

MANEUVER SCHEME

MARSHALLING AREA

MINE FIELD

MISSILE LOCATION

NUCLEAR WEAPON LOCATION

OBJECTIVE AREA

OBSERVATION POST

OFFENSIVE PLANS

OFFENSE VULNERABILITY

PATROL ROUTE

PERIMETER

PHASE LINE

POL SUPPLY

RADAR LOCATION

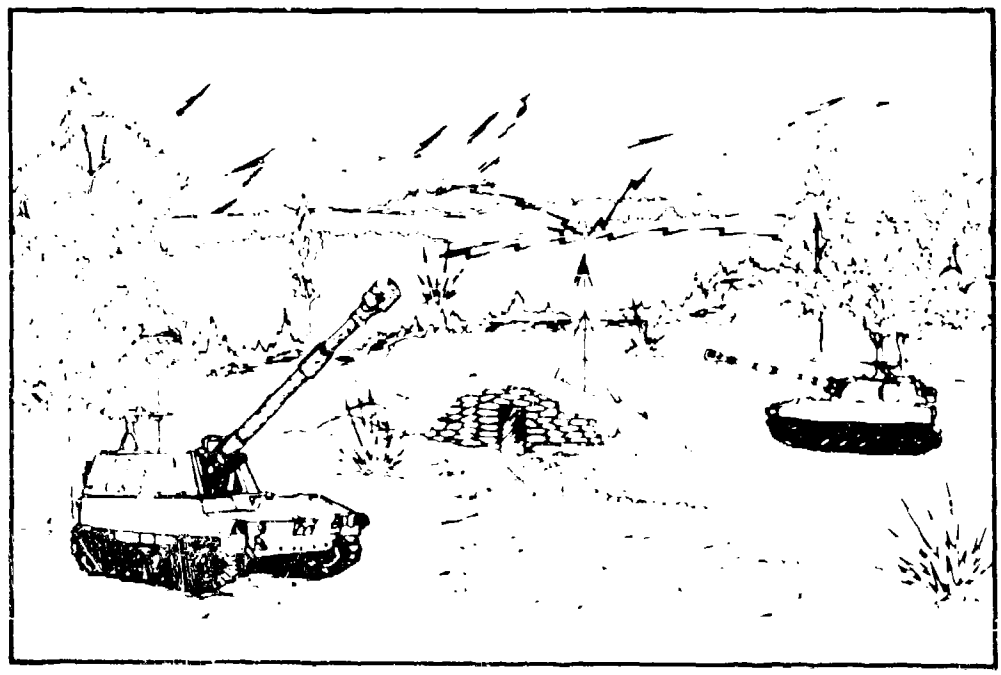
RESUPPLY LOCATION

SHORTAGES (CRITICAL)

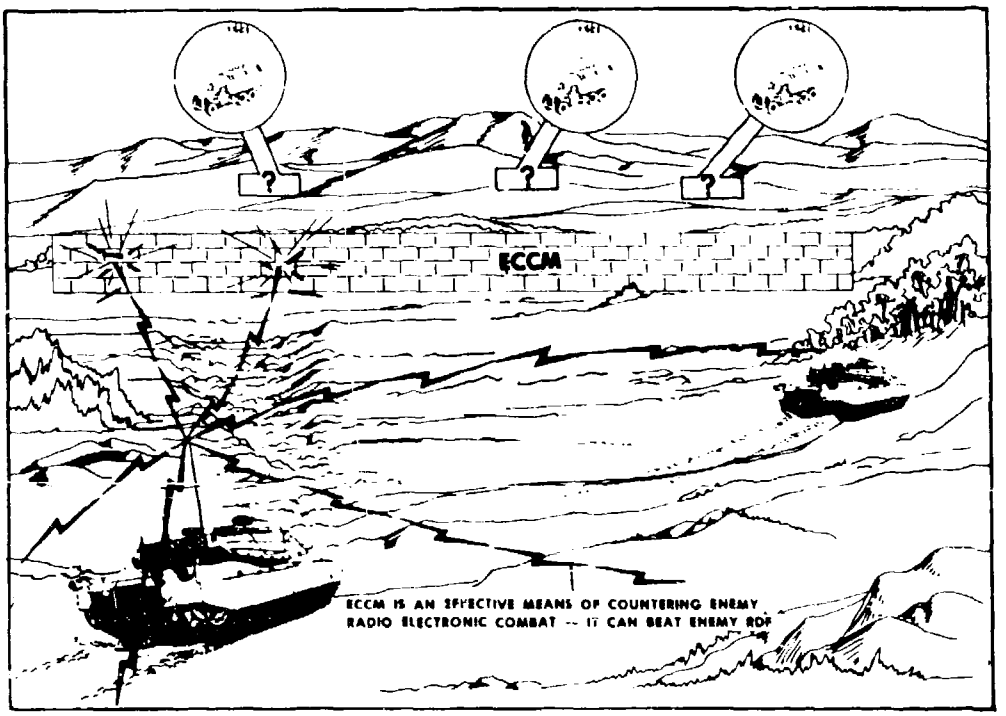
TACTICAL OPERATIONS CENTER

VIP LOCCATIONS

Electronic emitters can reveal locations of units, weapons, and command posts because . . .



location can be approximated by direction finding and then refined to an accuracy sufficient for target acquisition by plain text revelation; reference to terrain features by the operator; and terrain analysis.



ECCM IS AN EFFECTIVE MEANS OF COUNTERING ENEMY RADIOELECTRONIC COMBAT — IT CAN BEAT ENEMY RDF

GOOD ECCM TECHNIQUES

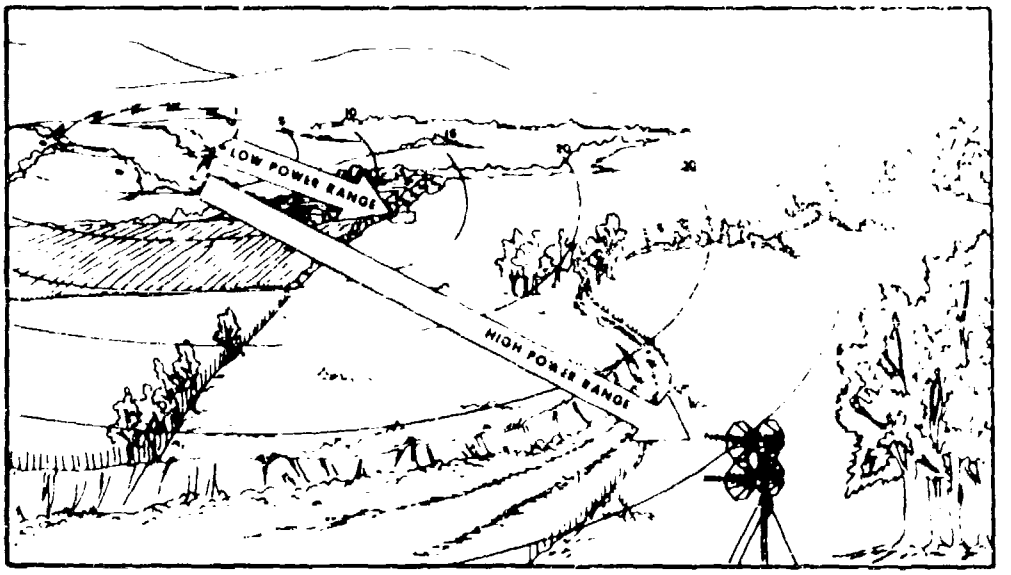
USE LOW POWER

When you transmit on lower power, you reduce the opportunity for an enemy to hear your signal. If the signal can't be heard, the transmitter can't be located by radio direction finding.

Obviously, if your own station can't hear the signal either, the radio is of little use. The trick is to use only enough ERP to be heard within your net, but not enough to be heard by the enemy. This is accomplished by thoroughly understanding radio wave behavior, and by using lower power wherever possible and the best antenna for each situation.

Unfortunately, tactical VHF radios have only two power settings: *low* and *high*. Most operators use only the high setting because they incorrectly think high power is better and that the low power position is useless. The lowest power setting available on the equipment should be tried first. Let us look at the following examples.

A tank platoon will operate in formations in which its tanks will be separated from one another by about 100 to 1,000 meters. Even when the tank's VHF/FM radio is set on low power, the radio transmits an effective signal which may be received by radio direction finders at a distance in excess of 10 kms, and perhaps as far as 30 kms. On the high power setting, a radio direction finder may be able to intercept the signal at a distance from 30 to 80 kms. ARDF can certainly intercept the high power signal at a distance of 80 kms.



One simple operator procedure to reduce ERP of the AN/VRC-12 and AN/PRC-77 radio using a lower power setting is bend and tie the AS 1729 toward the ground. This technique may not be possible with future shorter antennas that are expected in the inventory in the coming decade.

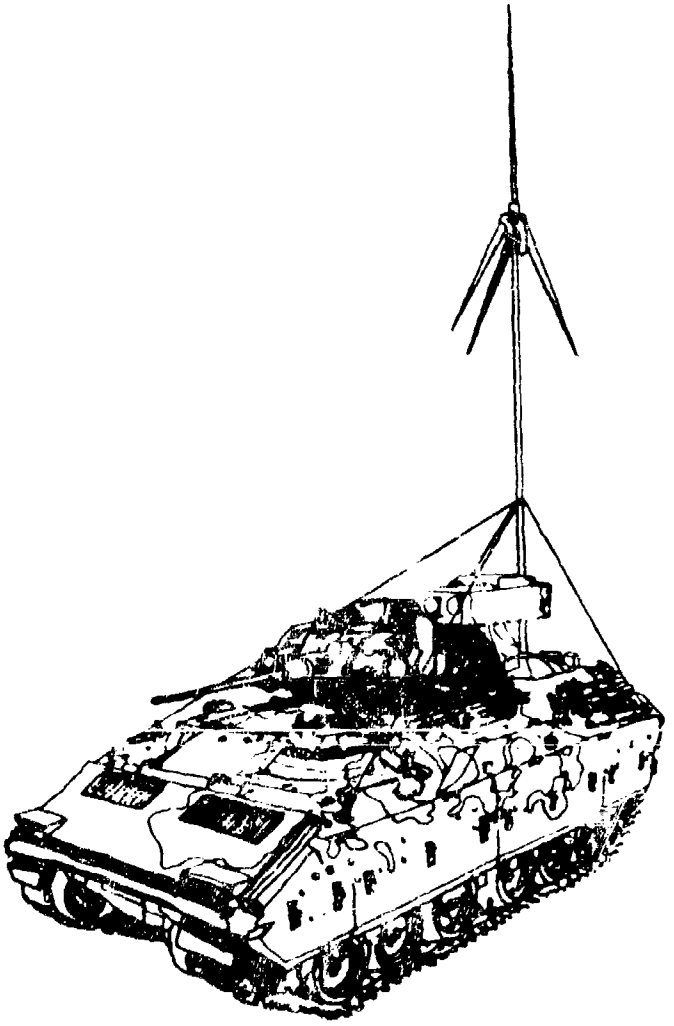
CAUTION

DO NOT TRANSMIT USING ONLY THE ANTENNA STUB OR WITHOUT ANY ANTENNA AT ALL

Using the AN/VRC-12, AN/PRC-77, or AN/PRC-74 radios without an antenna or with only the antenna stub results in severe mismatch of the power output stage. At certain frequencies, this mismatch is so severe that the maximum safe operating limits for the power amplifier transistor could be exceeded causing permanent damage to the radio!

Another method of reducing ERP and distorting the radiation pattern in the horizontal plane is to carry the AN/PRC-77 upside down with the antenna tip a foot above the soil. This technique will usually provide a good strong surface wave within a radius of five kilometers while reducing the radius of the direct wave most usable to RDF and ARDF.

Use the smallest antenna which will permit effective communications. Do not hesitate to take the extra step of changing from a ground plane antenna to a short-whip antenna whenever possible.



2

USE A MOBILE ANTENNA

This procedure provides a highly mobile command net antenna which can be rapidly relocated, and does not tie a command post to an antenna array.

USE DIRECTIONAL HORIZONTALLY POLARIZED ANTENNAS

For versatility, the omnidirectional vertically polarized antenna is best. The flexibility provided by omnidirectional antennas is important to the commander during the attack, when it is difficult to maintain correct orientation for horizontally polarized directional antennas. Vertically polarized omnidirectional antennas are required for communications between moving vehicles. However, when ECCM is considered, the omnidirectional antenna has one chief disadvantage — a danger. Omnidirectional antenna signals travel in a 360-degree radius and usually well across the FEBA where they are susceptible to intercept and RDF. Horizontally polarized directional antennas should be considered for lateral communications whenever possible.

Enemy forces primarily use Adcock and vertical loop RDF antennas which are designed for optimum performance when receiving vertically polarized radio waves. A horizontally polarized transmitting VHF antenna will radiate a predominantly horizontally polarized wave from ten to forty kilometers from the transmitter. The horizontally polarized wave will create some bearing error in an Adcock antenna, and a very large error in a vertical loop antenna. This may cause an error as much as five times greater than the usual operational error (about 20 degrees), creating unusable RDF bearings. It is impossible for an RDF operator to continually adjust tactical ground operated RDF equipment, particularly Adcock antennas, to compensate for both vertical and horizontal waves. If US forces would use both vertically and horizontally polarized omnidirectional and directional VHF antennas along with good COMSEC practices, direction finding would become more difficult and expensive for our adversary.

End- or center-fed half-wave or quarter-wave directional antennas offer many advantages with VHF radios. For example, a doublet antenna provides a more directional signal antenna which can reduce the enemy's ability to intercept the signal by 20 to 40 percent. It also provides a 20 percent greater range, especially in wooded areas, by increasing ERP in the desired direction. This is a useful ECCM technique.

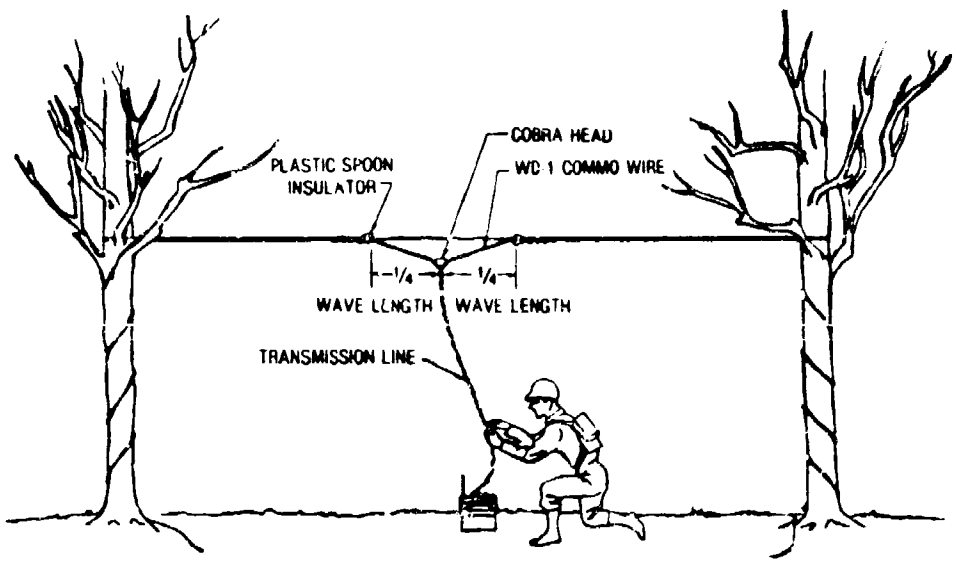
FORMULA FOR 1/2 WAVE ANTENNA

$$\text{Antenna Length In Feet} = \frac{468}{\text{Frequency In MHz}}$$

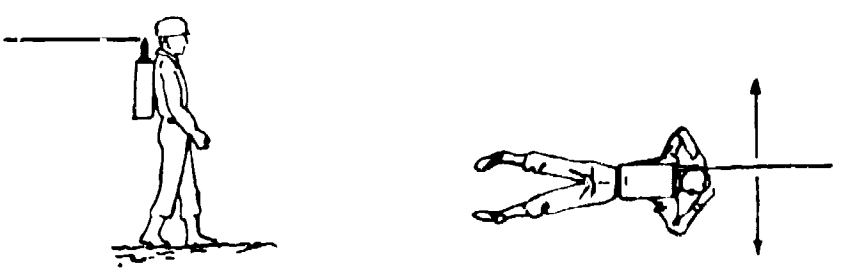
FORMULA FOR 1/4 WAVE ANTENNA

$$\text{Antenna Length In Feet} = \frac{234}{\text{Frequency In MHz}}$$

A VHF directional antenna is small — only nine feet long for a frequency of 50 MHz, or 6.5 feet for a frequency of 70 MHz. An antenna of this size is easily concealed. Doublets are also easily constructed from copper wire (or landline), a "cobra head," and two plastic C-ration spoon insulators. Yes, there are drawbacks — when one station uses a horizontally polarized antenna, so also should the other station; and correct antenna orientation between both stations is important. But, the advantages, particularly in a defensive situation, warrant consideration of this technique wherever practical. Antennas of this type are not suitable for fast-moving offensive operations. A horizontally polarized directional antenna provides the commander an alternative — just as a white phosphorous (WP) artillery round is an alternative, not a substitute for a highly explosive (HE) artillery round.



Horizontally polarized center-fed doublet antenna for AN/PRC-25 or AN/PRC-77 radio. (See TM 11-2651 and TM 11-5820-467-15.)



Antenna horizontal. (Radiation directional and at right angles to antenna.)

Advantages of Half-Wave Horizontally Polarized VHF Antennas in Comparison to Vertically Polarized Antennas:

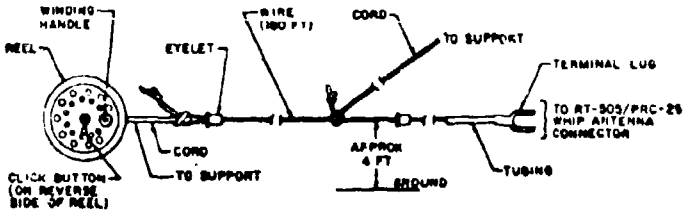
- **The horizontal antenna produces a more stable signal in the presence of interference (jamming).**
- **The horizontal antenna produces a more stable signal when used in or near dense woods.**
- **The horizontal antenna is more readily camouflaged without loss of signal.**
- **Small changes in antenna location do not cause large variations in signal strength.**
- **The horizontal antenna is more difficult to direction find because of polarization and because its signal can be directed to intended recipients and away from enemy RDF in many applications.**

Horizontally polarized antennas may be constructed by following instructions in —

TM 11-5820-667-12 (long wire for AN/PRC-77 radio)
TM 11-2651 (antenna groups AN/GRA-4 and AN/GRA-12, center-fed doublet)
TM 11-5820-467-15 (antenna group AN/GRA-50).

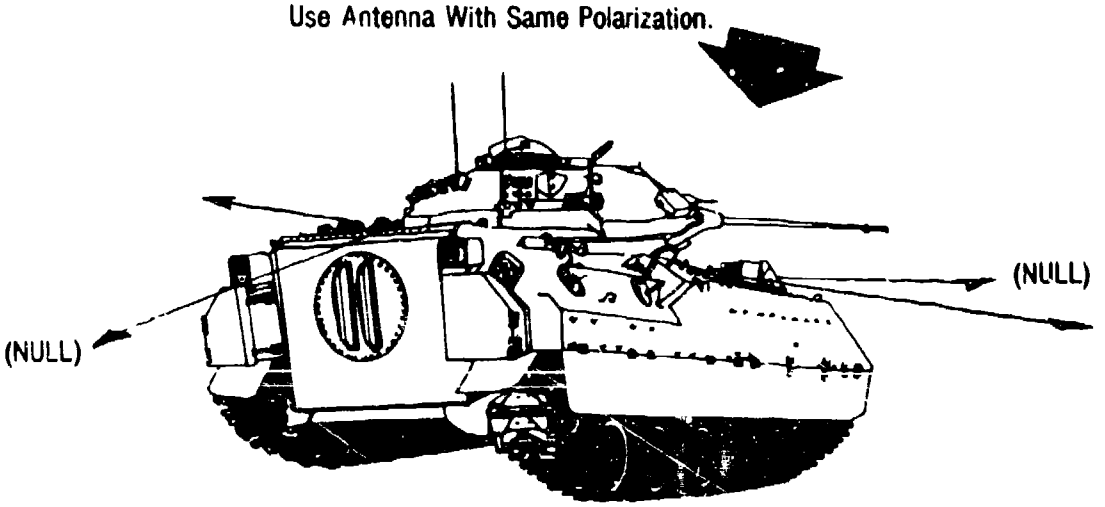
While the information provided in these manuals is tailored for HF application, the dipole dimensions can be readily scaled down for the particular operating frequency in the VHF range at the proper 50-ohm impedance required by the AN/PRC-12 and AN/PRC-77 radios.

RF cable assembly CG-692/U which has an insulator IL-4/GRA-4 permanently attached can be used to feed a doublet antenna.



AT 984A/G used to make end-fed antenna for AN/PRC-77 radio. (See TM 11-5820-667-12.)

Both Transmitting and Receiving Stations Should Use Antenna With Same Polarization.



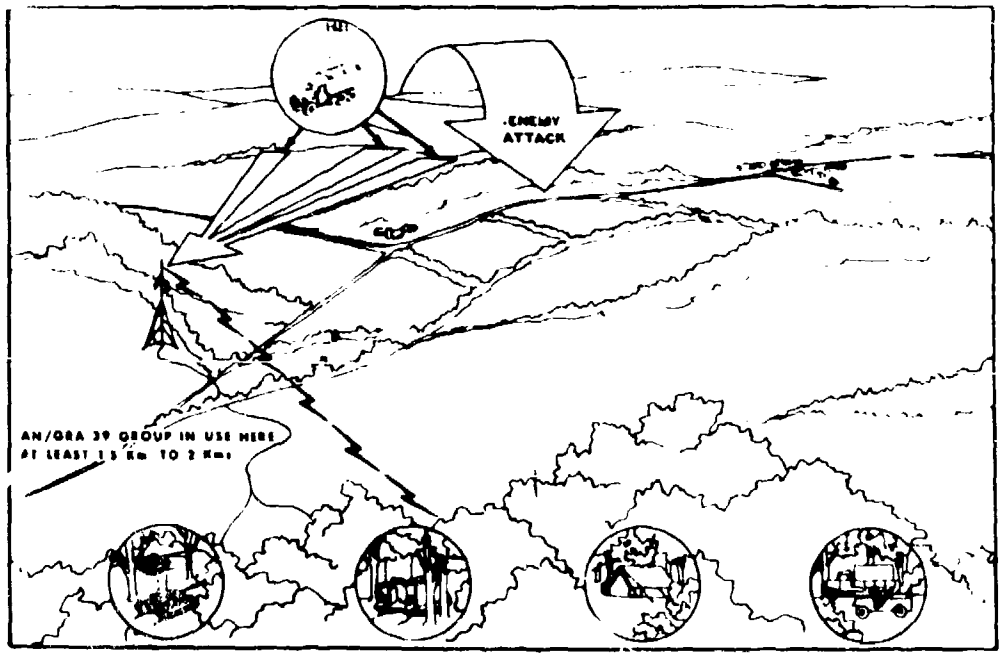
APC Serves as Counterpoise

HORIZONTALLY POLARIZED DIRECTIONAL ANTENNAS INCREASE OPERATING RANGE BY 20 PERCENT IN WOODED TERRAIN WHILE REDUCING THE ENEMY'S OPPORTUNITY TO INTERCEPT BY 20 TO 40 PERCENT.

4

DECOY ANTENNAS

When practical, surplus decoy antennas can be set up in credible antenna locations within 2,000 to 5,000 meters of the command post. Intelligence analysts place special emphasis on photographs or reconnaissance reports of visible antenna arrays. Real antennas, especially distinctive microwave antennas, must be carefully camouflaged.



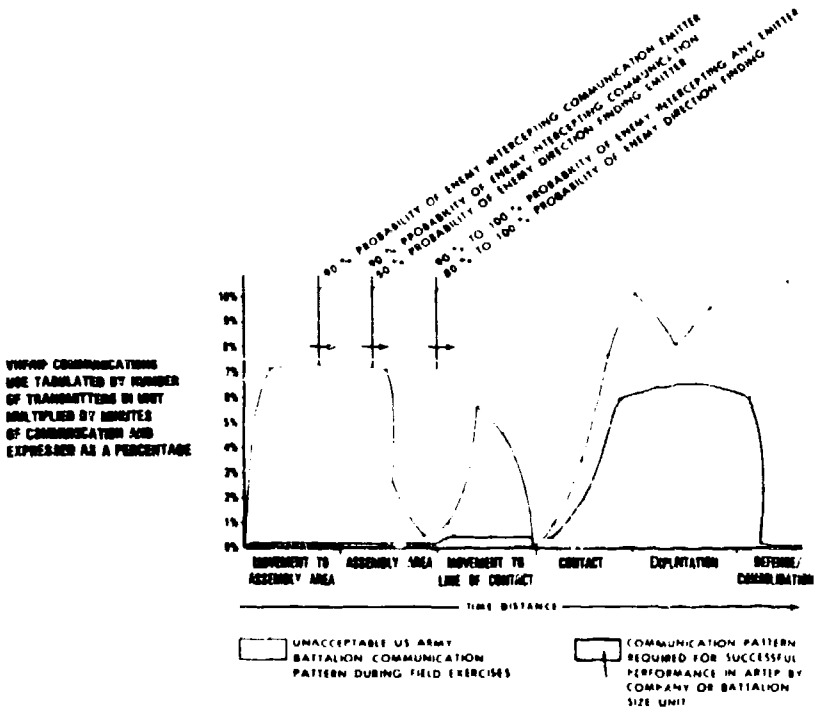
REDUCE COMMUNICATIONS TIME

Another way to reduce the probability of signal intercept by the enemy is to use radio communications only when necessary. Consider the use of landline communications where practical; use personnel as guides rather than providing direction and location over the radio. Once station identity is confirmed (ALPHA ONE BRAVO ONE SIX, THIS IS ALPHA ONE BRAVO TWO SEVEN), eliminate call sign redundancy by using the last letter of the changing portion of the call sign plus the suffix (BRAVO ONE SIX, THIS IS BRAVO TWO SEVEN). Call sign procedure is not a substitute for authentication. Limit conversation to less than 30 seconds — a 20 second signal is ideal.

Enemy RDF is not as effective once an offensive operation has begun. We are usually moving too fast. Short communication time is not as critical during the battle; but short communications as a counter-RDF technique are vital during the preparation phase, the approach to the objective, or in the defense. Since the discovery of the displacement of a reinforcing unit is critical, the reserve force should not use radio communications unless necessary.

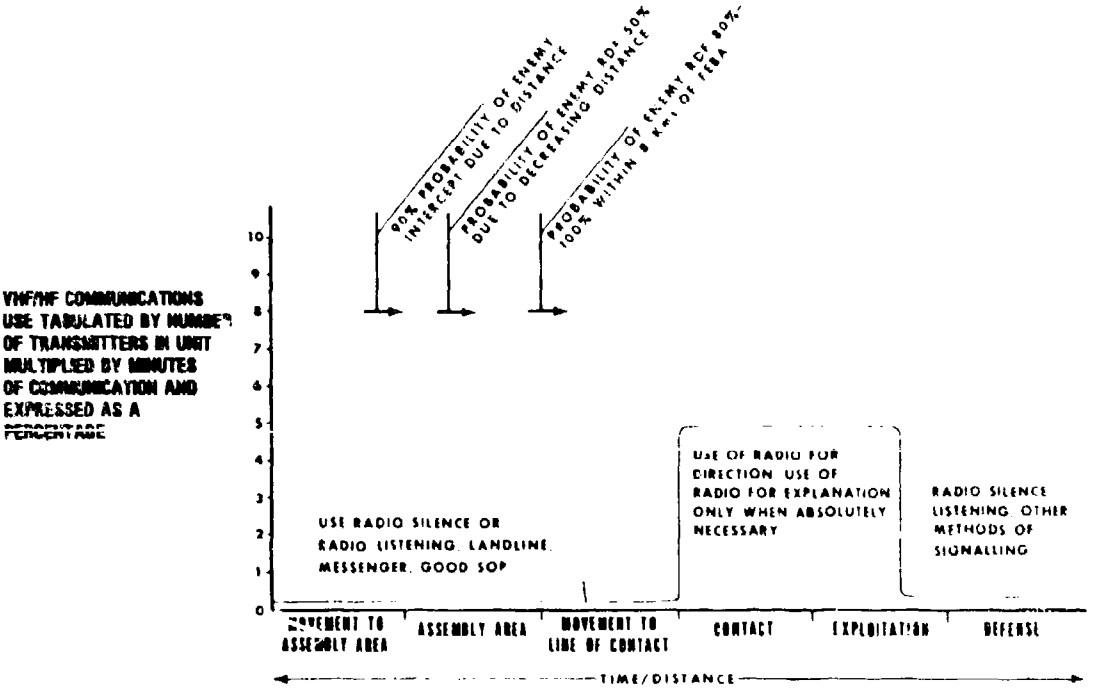
An observant enemy notices that in too many instances US Army tactical communications may be used as a substitute for complete battle planning. Analysis of US tactical communications, illustrated in the following graph, indicates that most communications used in training exercises are explanatory, not directive in nature. Tactical communications should be used to rapidly convey decisions, to key standing operating procedures, and to direct alternative courses of action. Execution of the battle must be inherent in training, planning, ingenuity, and team work. Vulnerability of communications to intercept and direction finding is indicated by the large volume and context of communications noted on command links prior to contact with the enemy. This pattern uniquely distinguishes the US Army in the attack prior to its departure from the assembly area. Additionally, the communications pattern depicted in the graph defies electronic concealment. There is too much traffic to be concealed. By contrast, the preferred communications pattern (indicated by the shaded area of the graph) can be concealed prior to contact.

Vulnerability to enemy RDF increases as the FEBA is approached.


90 % PROBABILITY OF ENEMY INTERCEPTING COMMUNICATION EMITTER
90 % PROBABILITY OF ENEMY INTERCEPTING COMMUNICATION
50 % PROBABILITY OF ENEMY DIRECTION FINDING EMITTER
90 % TO 100 % PROBABILITY OF ENEMY INTERCEPTING ANY EMITTER
80 % TO 100 % PROBABILITY OF ENEMY DIRECTION FINDING
VHF/HF COMMUNICATIONS USE TABULATED BY NUMBER OF TRANSMITTERS IN UNIT MULTIPLIED BY MINUTES OF COMMUNICATION AND EXPRESSED AS A PERCENTAGE
MOVEMENT TO ASSEMBLY AREA
ASSEMBLY AREA
MOVEMENT TO LINE OF CONTACT
CONTACT
EXPLOITATION
DEFENSE/ CONSOLIDATION
TIME DISTANCE
UNACCEPTABLE US ARMY BATTALION COMMUNICATION PATTERN DURING FIELD EXERCISES
COMMUNICATION PATTERN REQUIRED FOR SUCCESSFUL PERFORMANCE IN ARTEP BY COMPANY OR BATTALION SIZE UNIT

COMPARISON OF VHF/HF COMMUNICATION PERFORMANCE REQUIRED FOR SUCCESSFUL ARTEP VERSUS PREVIOUS HISTORICAL PERFORMANCES

***Army Training and Evaluation Program (ARTEP): (Designed to evaluate units in mission accomplishment as opposed to a test oriented atmosphere.)**

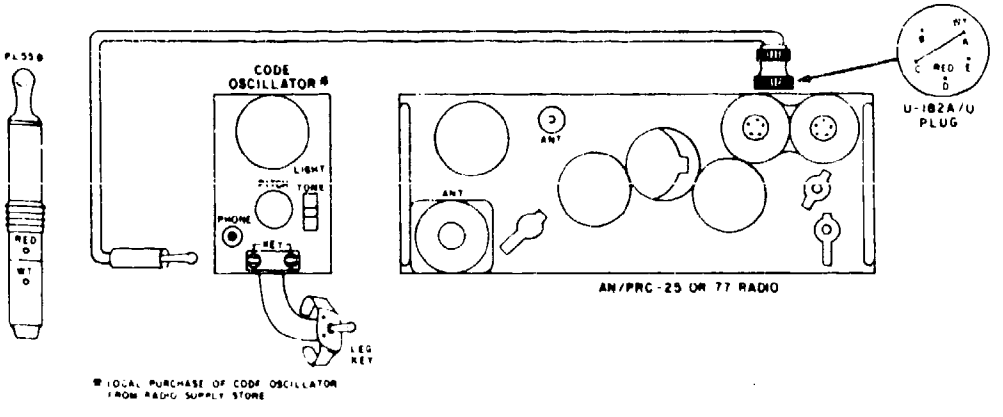

VHF/HF COMMUNICATIONS USE TABULATED BY NUMBER OF TRANSMITTERS IN UNIT MULTIPLIED BY MINUTES OF COMMUNICATION AND EXPRESSED AS A PERCENTAGE
90% PROBABILITY OF ENEMY INTERCEPT DUE TO DISTANCE
PROBABILITY OF ENEMY RDF 50% DUE TO DECREASING DISTANCE
PROBABILITY OF ENEMY RDF 80%- 100% WITHIN 8 K-1 OF FEBA
10
9
8
7
6
5
4
3
2
1
0
USE RADIO SILENCE OR RADIO LISTENING. LANDLINE. MESSENGER. GOOD SOP
USE OF RADIO FOR DIRECTION USE OF RADIO FOR EXPLANATION ONLY WHEN ABSOLUTELY NECESSARY
RADIO SILENCE LISTENING. OTHER METHODS OF SIGNALLING
MOVEMENT TO ASSEMBLY AREA
ASSEMBLY AREA
MOVEMENT TO LINE OF CONTACT
CONTACT
EXPLOITATION
DEFENSE
TIME/DISTANCE

VHF/HF COMMUNICATION MODEL FOR SURVIVAL ON THE MODERN BATTLEFIELD

6

CONSIDER THE USE OF MORSE CODE WITH VHF/FM IN PLACE OF VOICE WHERE PRACTICAL

Communications time can also be reduced by using an inexpensive (less than $15.00) radio code tone oscillator (used to practice Morse code and obtainable at radio supply stores) installed at the audio input of FM/VHF radios. This adaptation permits the transmission of short Morse code tone signals instead of voice signals, which are of long duration. The signal is clear, sharp, and perceptible at greater distances than is voice, and when used with a directional antenna, is an excellent COMSEC technique. Radiotelegrapher's Q and Z signals may serve as a basis for a divisional "Morse code" system. Special Forces and long-range reconnaissance units put FM/Morse code to good use in Vietnam.

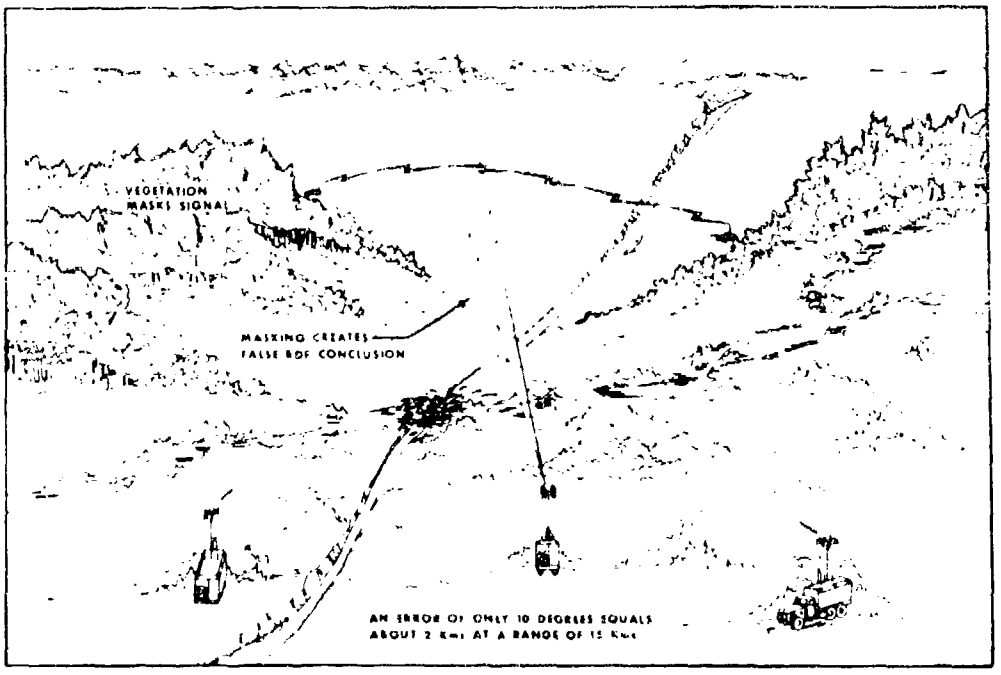


THIS IDEA IS A TECHNIQUE FROM THE FIELD. CONSULT THE UNIT C-E OFFICER FOR PROPER USE OF THIS TECHNIQUE OVER CONTROLLED VHF NETS.

7

ANTENNA MASKING

Antenna masking is the technique of hiding radio signals behind terrain. It is an inexpensive way tc confuse RDF efforts. VHF radio waves bend; they are reflected by buildings and mountains, and absorbed by trees. When this happens, it is difficult to determine the original direction from which the wave was transmitted, but the hearability of the signal is minimally affected. A radio operator can advantageously use this principle by attempting to place terrain obstacles between the transmitter and the FLOT, while affording an unblocked path to the intended receivers. Hills, lakes, and dense forests also provide terrain obstacles. Antenna masking also occurs when antennas are positioned on the back slopes of hills. A radio operator should also erect antennas as low as adequate communications permit; and, in all cases, antennas should be camouflaged to blend with terrain.


VEGETATION MASKS SIGNAL
MASKING CREATES FALSE RDF CONCLUSION
AN ERROR OF ONLY 10 DEGREES EQUALS ABOUT 2 km AT A RANGE OF 15 Km

AUTHENTICATE

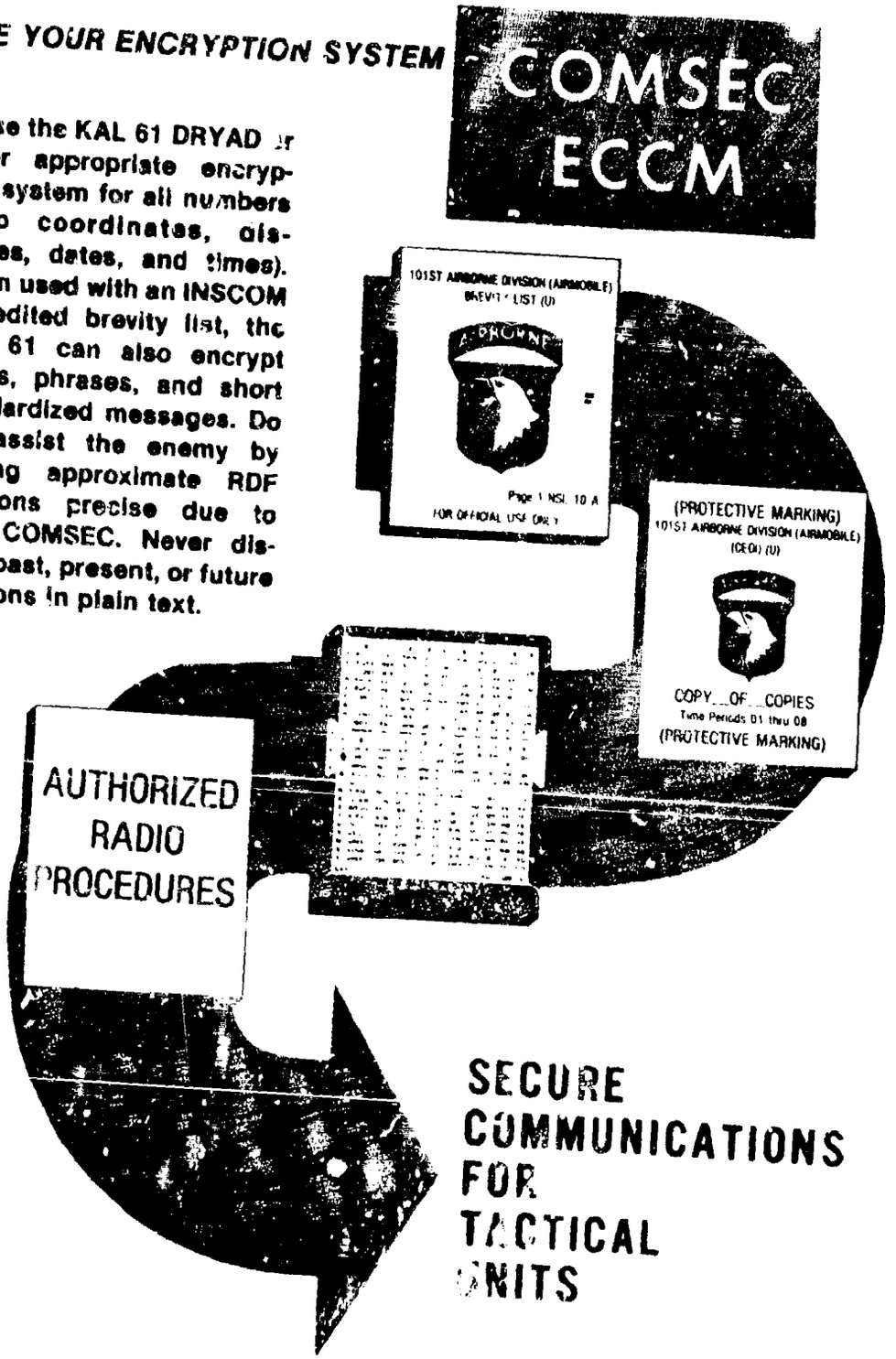
Be aware of imitative comr unications deception (ICD). Authenticate: ICD is frequently used by an enemy to prolong communicatior RDF thrives on prolonged communications. Don't be caught by the lure.

CHANGE CALL SIGN, FREQUENCY, AND SCHEDULE

Change call signs, frequencies, and schedules at least every 24 hours; change call sign suffixes as well. Don't circumvent the automated CEOI. These techniques reduce the enemy's ability to analyze RDF reports in conjunction with COMINT.

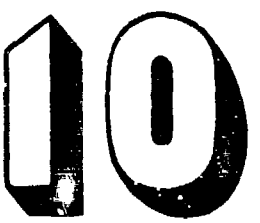
USE YOUR ENCRYPTION SYSTEM

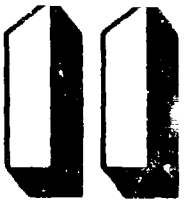
Use the KAL 61 DRYAD or other appropriate encryption system for all numbers (map coordinates, distances, dates, and times). When used with an INSCOM accredited brevity list, the KAL 61 can also encrypt words, phrases, and short standardized messages. Do not assist the enemy by making approximate RDF locations precise due to poor COMSEC. Never discuss past, present, or future locations in plain text.



RADIO OPERATORS MUST BE TRAINED!

Operation of a ¼-ton vehicle or a 16-mm projector is a comparatively simple task for most US Army personnel; nevertheless, a definitive training and licensing program is required to ensure personal and group safety as well as to prevent equipment abuse. In combat, misuse of the radio can result in the death of an entire unit. Use of any tactical radio should be restricted to individuals (especially officers) who continually demonstrate equal qualification in both radio-operator skills *and COMSEC*.



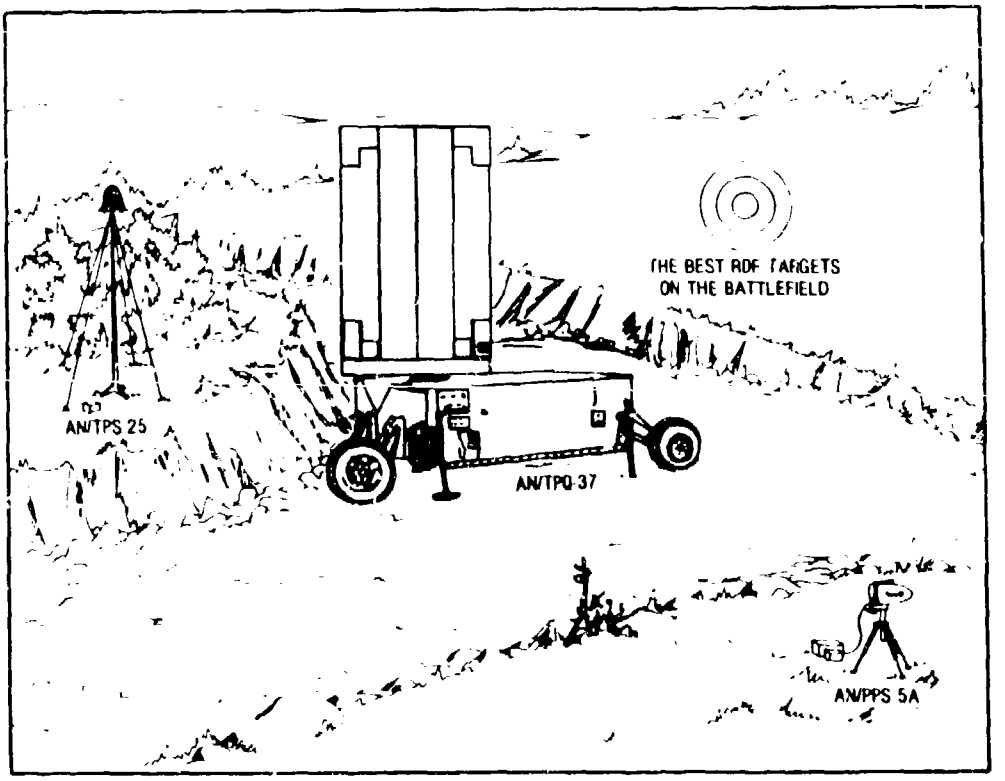


RADARS AND MICROWAVE TRANSMITTERS

Though this training circular pertains chiefly to RDF of VHF/UHF, FM, single channel communications emitters, radars and VHF microwave transmitters pose special problems to be considered in conjunction with communications emitters.

Radars are targets.

The nature of a radar wave (as opposed to an HF/VHF radio wave) makes direction finding of a radar very accurate and lucrative. Direction finding of radars can be very precise -- to within a CEP of 50 meters at a range of 10 to 20 kilometers. This accuracy is sufficient for directing immediate and effective artillery fire. Too frequently US Army units collocate radars with radio transmitters, especially in artillery units. Even when the radar operator practices good electronic security (ELSEC), the combination of radar signals and radio traffic provides considerably more SIGINT to the enemy than when both emitters are separated. This is an opportunity for better use of landline communications. *Do not locate radars near communications centers or command and control areas. Ensure radar equipment operators practice good ELSEC.*



RADIOELECTRONIC COMBAT (REC)

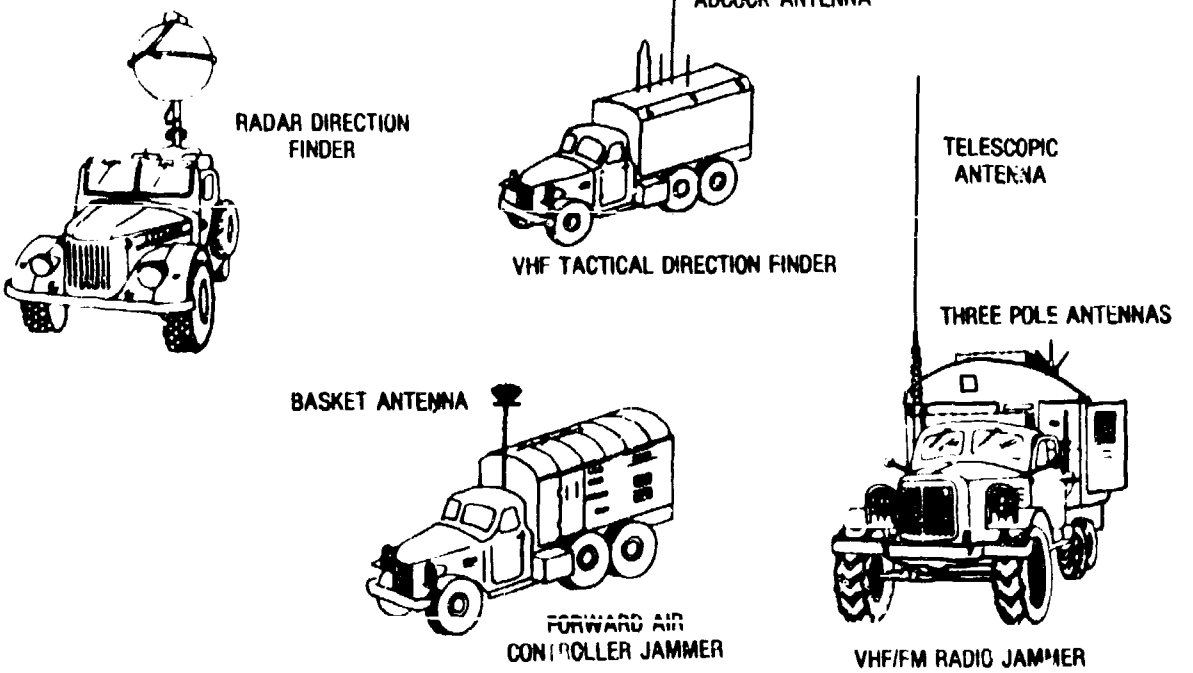
12

The most significant interference caused by Threat electronic warfare operations is called radio-electronic combat. REC differs from US electronic warfare in that there is a direct link between collectors and fire support means. The purpose of REC is to destroy or disrupt US command control means. Soviet REC units continuously intercept and analyze friendly communications and noncommunications emitters. As nets are identified, priorities are established for jamming and destruction.

The equipment below, usually found well forward on the battlefield, supports the enemy at all levels of command.

Enemy radio-electronic combat target priorities generally are as follows:

- Nuclear-capable artillery and Air Force units and associated command and control systems.
- Command posts, observation posts, communications centers, and radar stations.
- Other field artillery, tactical air support, and air defense units.
- Reserve forces and logistic
- Point targets that may jeopardize advancing enemy forces.



SOVIET RADIO-ELECTRONIC COMBAT EQUIPMENT

NONCOMMUNICATIONS INTERCEPT AND DIRECTION FINDING

A US Army division is allocated approximately 400 noncommunications emitters (to include radar sets, navigational beacons, aircraft landing systems, identification as friend or foe (IFF) devices, drone control units, fuzes, electro-optic devices, searchlights, and meterologic data gathering systems). Although these systems vary widely in electronic characteristics and in method of deployment, they usually radiate electromagnetic energy into potentially hostile territory where it is vulnerable to intercept and analysis by enemy SIGINT units.

Intercept of Emissions.

Signal strength and the amount of operating time are two major factors which must be considered in determining the interceptability of various noncommunications emitters. Powerful radar signals can be intercepted at distances five times greater than their operating range; i.e., a radar searching for targets with a maximum range of five kilometers would be vulnerable to intercept at distances in excess of 25 kilometers. This is because the radar intercept operator intercepts the strong emitted signal and is not forced to receive the weak echo signals required by the radar operator. Early warning and surveillance radars must operate for prolonged periods of time to accomplish their surveillance mission; therefore, they are extremely vulnerable to intercept. Fire control and guidance radars operate at brief or intermittent periods, causing them to be less susceptible to intercept. However, regardless of the duration of the operating period, all radiations are vulnerable to intercept.

Signal Analysis.

Important signal information is contained in the technical characteristics or parameters of the noncommunications emitter signal and its direction of arrival. Signal analysis can reveal the type and function of the emitter; and the direction of arrival information can permit location of the emitter. The basic parameters of the emitted signal are:

The *carrier frequency* is obtained from the tuning dial of the receiver or, more accurately, from a frequency counter.

Modulation characteristics, which include pulse width, pulse recurrence display frequency, and pulse shape are obtained from an oscilloscope display of the detected video waveform.

The *direction of arrival* is derived from the orientation of the directional receiving antennas.

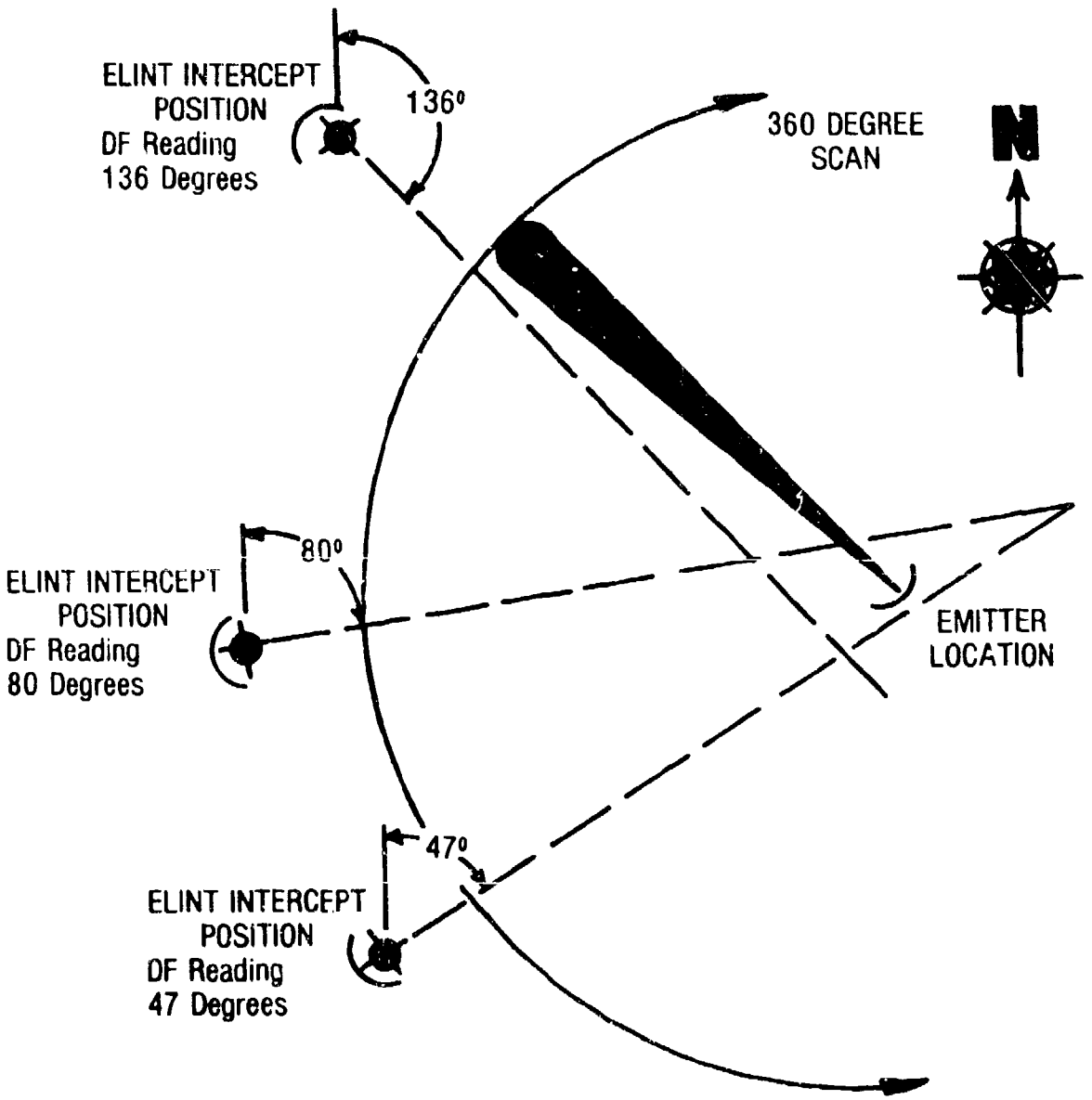
The *antenna scan* measurement is derived from the pattern displayed on the oscilloscope or detected audibly by means of a headset.

The amount of *radiated power* is estimated from signal strength measurements and the distance from the emitter.

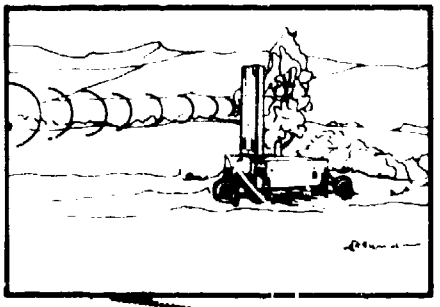
These characteristics are then examined to determine the type of emitter and the control function or weapon system with which it is used. No two friendly emitters have the same combination of carrier frequency, pulse repetition rate, or pulse width. If the received signal has some unusual characteristic, the emitter can be uniquely identified or "fingerprinted." The movement of the emitter can then be tracked as it is deployed at various locations, providing reliable intelligence information.

Direction Finding Emitter Location.

Because of the sharpness of the radar wave, highly directional antennas, which have an appreciable output signal only when oriented toward the emitter, are able to provide very accurate direction finding information. Direction finding from two or more radar direction finders permits a radar emitter to be located by applying basic trigonometry or by plotting the data as shown in the figure. The CEP of radar emitter locations is sufficient to direct artillery or missile fire.

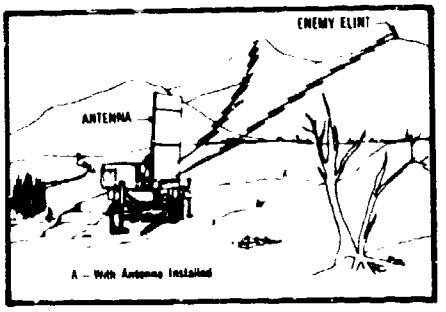


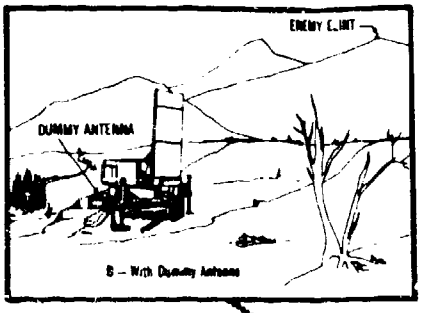
EMITTER LOCATION USING DIRECTION FINDING TECHNIQUES



ECHO BOX TEST

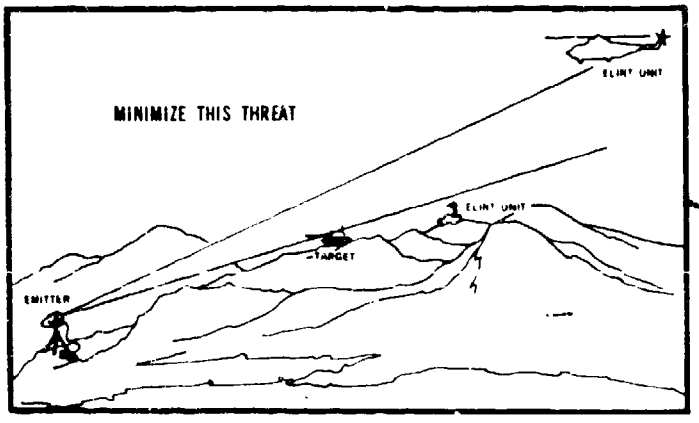
When calibrating radar point antenna towards friendly terrain



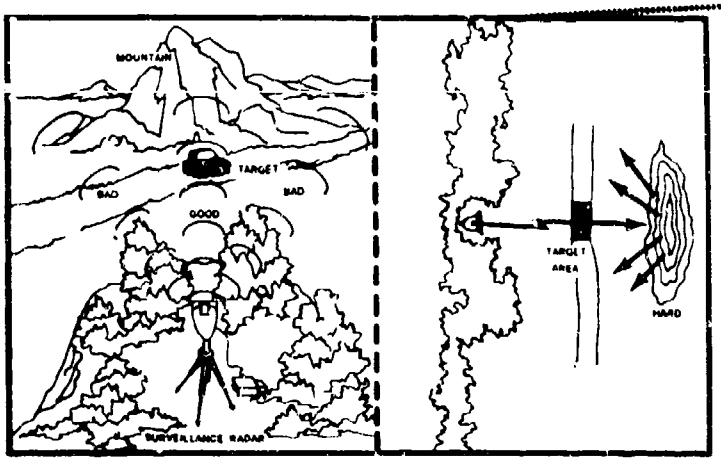


CIRCUITRY TESTS, DUMMY ANTENNA

A dummy antenna absorbs and dissipates RF energy rather than radiating the energy thus minimizing the probability of intercept

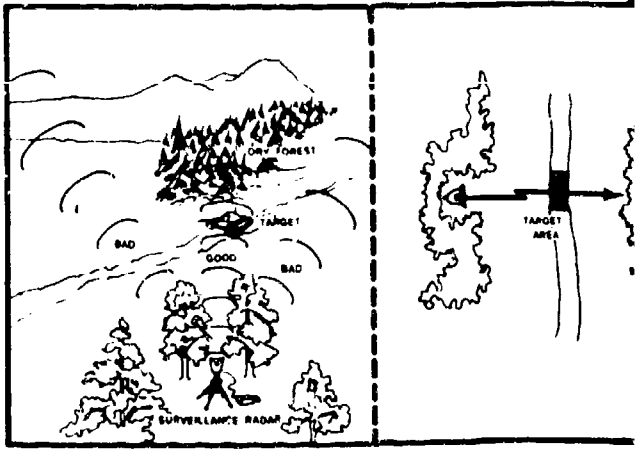


Sitting below and over target area lowers chances of intercept by ground based intercept, but increases chances for intercept by airborne intercept by a factor of 4 to 5. Sitting above and under the target area, lowers the chances of intercept from airborne intercept, but increases chance for intercept by ground based intercept. It is preferable to site under target areas, as ground based intercept is less effective than airborne intercept systems



BACKGROUND SELECTION, HARD

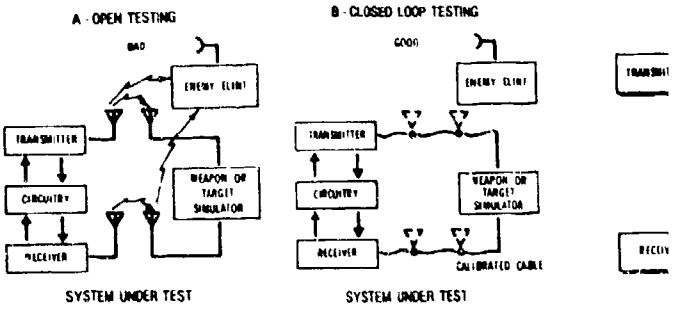
Hard backgrounds reflect electronic radiations, and increases the probability of intercept by the enemy. However, it is better to use hard background than no background



BACKGROUND SELECTION, SOFT

Use soft backgrounds whenever possible. Such backgrounds absorb emissions, thus minimizing its probability of enemy intercept

SUMMARY OF OPERATIONAL ELSEC TECHNIQUES



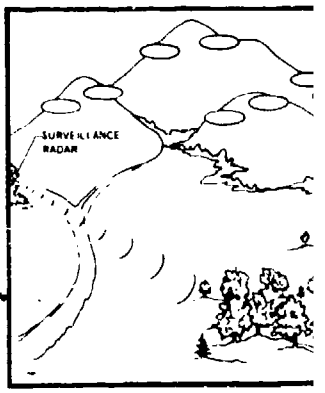
CLOSED LOOP TESTING

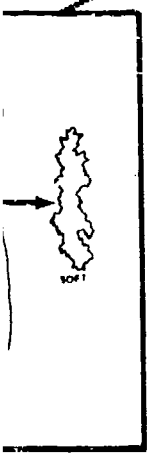
Closed loop testing denies intercept of intentional and spurious emanations.

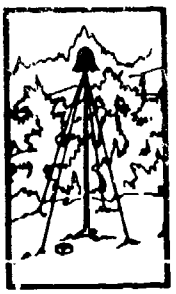
I Techniques to Reduce the Probability of Intercept

	Maintenance	Operator	Training	Installation
A Reduced Operating Time				
Use of Dummy Antenna	●		●	●
Closed Loop Testing	●			●
Reduced Power Testing	●	●	●	●
Antenna Orientation	●	●	●	●
Equipment Sharing		●	○	
B Reducing the Illuminated Volume				
Reduced Effective Radiated Power	●	●	●	●
Reduced Antenna Scan or Beamwidth	●	●	●	●
C Operator Techniques				
Frequency Changes (Frequency)	○	●	○	
Change of Operating Time (Time)	○	●		
Change of Operating Location (Place)	○	●	○	○
D Equipment String				
Side and Back Lobe Absorption		●	○	●
Target Background Considerations	○	●	○	●
II Techniques to Reduce the Information Content				

1 VARY NUMBER & TYPE OF EMITTERS
2 VARY EMITTER SIGNAL PARAMETERS

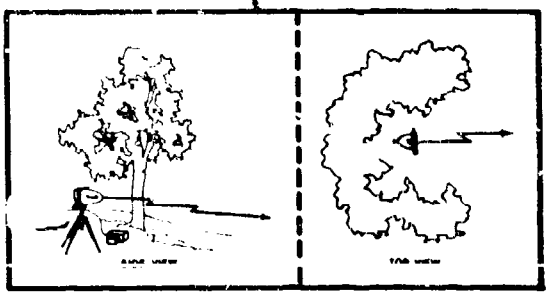






ALL EMITTERS SHOULD BE TURNED OFF WHEN NOT PERFORMING A USEFUL FUNCTION

(Especially for this piece of equipment)



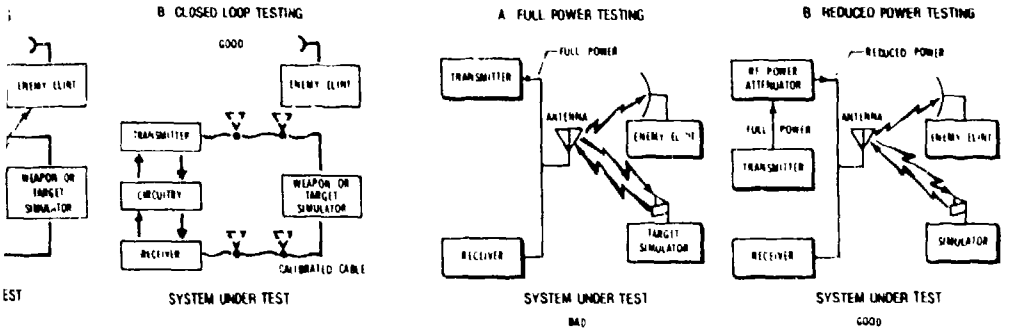
TUNNELING; SIDE, REAR AND TOP

To control rear, side, and top lobes (no terrain or site to maximize spurious emanations.

To identify the enemy will ch emitter use and the frequency must is operating, and to loca direction finding

MOST US ARMY RADAR EMITTERS DO NOT HAVE THE ABILITY TO VARY THEIR FREQUENCY

THREE DIM

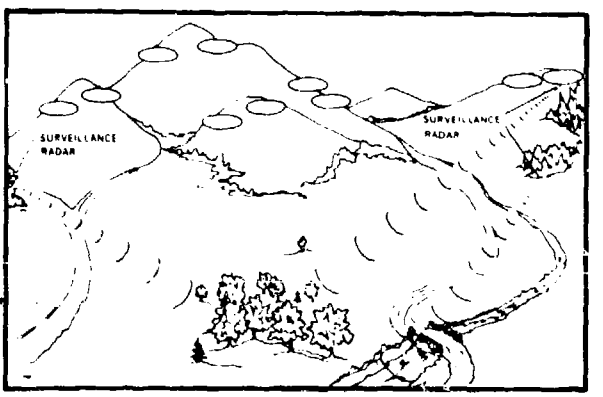


OSED LOOP TESTING

...es intercept of intentional and spurious emanations.

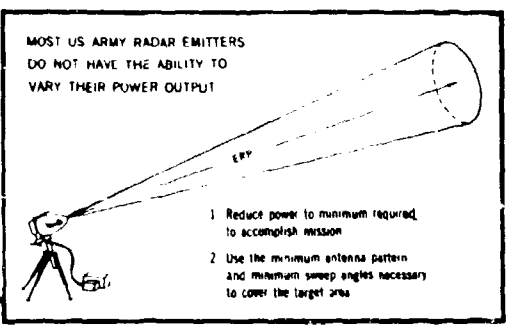
REDUCED POWER OPERATION

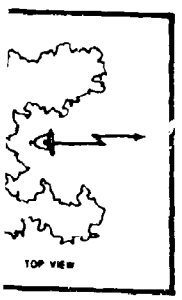
The less power used the more difficult it becomes to intercept an emitters signal



ELSEC THROUGH EQUIPMENT SHARING

When a target area may be covered by more than one radar unit a good elsec technique is to share the search mission by operating the emitters at alternate times Such a practice reduces the probability of intercept and may confuse the enemy force as to the exact number of units in the area


MOST US ARMY RADAR EMITTERS
DO NOT HAVE THE ABILITY TO
VARY THEIR POWER OUTPUT
1 Reduce power to minimum required to accomplish mission
2 Use the minimum antenna pattern and minimum sweep angles necessary to cover the target area



ID TOP

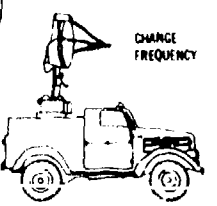
...ate spurious emanations

To identify, the enemy will attempt to use the time of emitter use and the frequency on which the equipment is operating, and to locate US emitters, will use direction finding

SO MINIMIZE THIS THREAT

DON T USE EQUIPMENT ON A REGULAR SCHEDULE

DIRECT AZIMUTH SCANS SUCH THAT THEIR MAIN RADIATION BEAM WILL RADIATE MINIMUM POWER AT THESE SITES



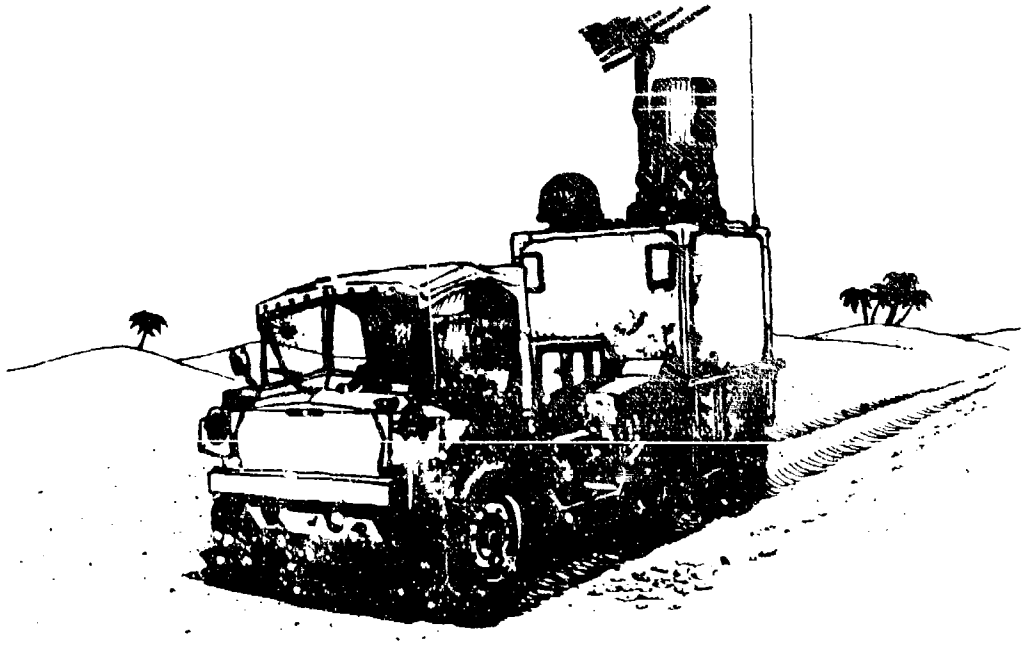
MOST US ARMY RADAR EMITTERS DO NOT HAVE THE ABILITY TO VARY THEIR FREQUENCY

THREE DIMENSIONS OF RADAR DETECTING AND LOCATING

13

JAMMERS ARE TARGETS TOO

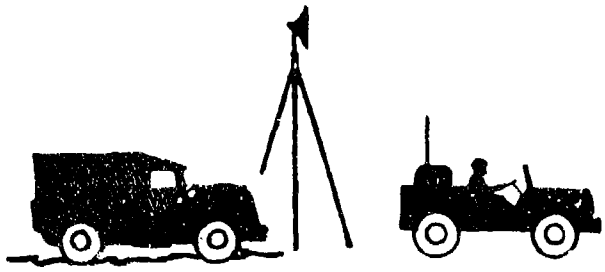
Friendly jammers also make up a large portion of RDF electromagnetic targets on the battlefield. No longer can these high radiation devices be deployed to the highest terrain to operate for extended periods. The modern battlefield requires highly mobile jammers capable of moving constantly while still operating. The high amount of radiated power and the peculiar signal transmitted by jammers enable enemy RDF to easily identify them as targets for suppressive fires. Deployment of tactical jammers requires optimum SIGSEC tactics.



Jammers must radiate large power levels across the FLOT and be located close to the FEBA. These conditions create considerable vulnerability with a high probability of intercept and accurate DF locations. Jammers should be sighted in locations that offer more than one exit. Jammers will also be targets of opportunity for enemy reconnaissance units as well as unconventional forces. Operators should be well versed in all aspects of security.

A Few Words About Microwave Transmitters.

Microwave communications systems use highly directional antennas. An RDF has to be directly in the path of the microwave signal before it is effective and then the distance to the transmitter is difficult to measure accurately. It is not uncommon, however, to observe microwave system operators using an HF or VHF radio with an omnidirectional antenna to communicate from one end of a microwave link to the other. HF or VHF communications usually reflect service traffic distinctly familiar only to microwave systems — used at command posts.



MULTICHANNEL LINK

AN/GRC 106
VOICE ORDER WIRE

COUNTER-DF COMBAT STEPS

You can beat RDF by using these techniques:

- Reduce transmit power to minimum level required to permit communications.
- Use mobile antennas where practical.
- Use horizontally polarized directional antennas where tactical utility permits.
- Remote radios one kilometer or more.
- Use decoy antennas.
- Transmit as quickly as possible, then get off the air. Organize message content beforehand to minimize transmission time and consider not transmitting the message by radio or telephone if alternate means exist.
- Site radio station with obstacle between it and enemy to reduce possibility of intercept. This is referred to as antenna masking.
- Use proper authentication procedures.
- Train radio operators.
- Take special care with radars and microwave transmitters.
- Take special care with jammers.
- Use encryption devices to prevent the enemy from refining RDF locations with measurement data provided through poor COMSEC. Use proper call signs.
- Use dummy load (antenna) for maintenance and tune-up procedures.
- Employ random transmissions, rather than working on a schedule to reduce the enemy's ease of interception.
- Do not peak traffic before an attack or any major change in strategy.
- Use radar blinking where practical.

*U.S. GOVERNMENT PRINTING OFFICE: 1977-735-895/45